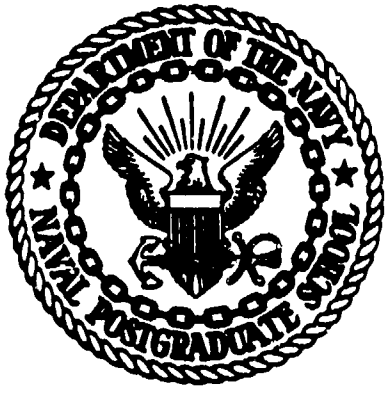
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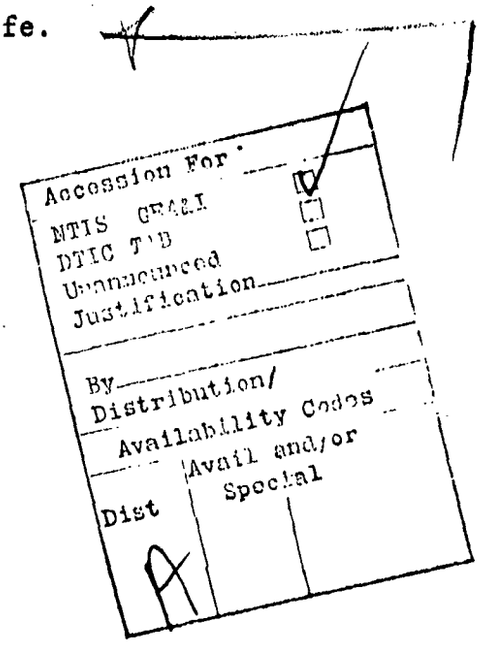
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This thesis investigates methods of controlling maintenance costs over the life of range systems. The theories of life-cycle costing (LCC) and integrated logistic support (ILS) are examined. Difficulties in funding range equipment replacement are reviewed. Methods of controlling maintenance costs are scrutinized. Financial management and financial reporting at PMTC is reviewed. It is concluded that LCC techniques and ILS analysis should be implemented in range equipment design. Furthermore, maintenance management should be given greater latitude in controlling maintenance costs over equipment life.



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Maintenance Cost Control At

The Pacific Missile Test Center

by

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Lieutenant, United States Navy
B.S., United States Naval Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

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ABSTRACT

The Pacific Missile Test Center (PMTC) is the Navy's largest Major Range and Test Facility Base, with an investment of over one billion dollars. The majority of this investment is in range test equipment and facilities including radar, telemetry, communication and command/control systems. Concern is growing over the "excessively obsolete condition of PMTC technical equipment." Improvement of factors concerned with the maintenence function is one means of remedying this problem.

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I. INTRODUCTION

A. PROBLEM STATEMENT

The Pacific Missile Test Center is the Navy's largest Major Range and Test Facility Base (MRTFB), with an investment of over one billion dollars. The majority of this billion dollar investment is in range test equipment and facilities.[1] The growing concern over the present inflationary period, highlighted by spiraling labor and material costs, has caused broad public debate over the size of the defense budget. Attention has been focused on the effective management and utilization of existing equipment, resources, and the efficient future expenditure of funds.

Maintenance of test range equipment and facilities is considered significant in the effective management of the billion dollar investment at the Pacific Missile Test Center (PMTC). The maintenance function is considered of importance for two reasons. First, a major goal adopted by the Commander, Pacific Missile Test Center for FY-80 was to "develop a comprehensive plan and initiate its implementation, that will provide for the reduction of the excessively obsolete condition of PMTC technical equipment." Second, the goal of the maintenance activity is to enhance the effectiveness and operational performance of range test equipment and facilities at PMTC. During fiscal year 1979, approximately 2.8% of the funds received through

institutional funding (program element 65864N) were budgeted toward depot-level maintenance (DLM) activities.[2] As a result of the large capital investment in test range equipment and facilities, the maintenance function plays an important role in determining the operational effectiveness and availability of test range equipment and facilities for test and evaluation purposes. Additionally, it is viewed as a means of preventing range technical equipment from deteriorating to a condition of obsolesence.

At PMTC, the depot-level maintenance function is managed by the Design and Engineering Department (code 4100) through its Inservice Engineering Division. Depot-level maintenance includes all maintenance performed on range test equipment and facilities which is not performed by operating personnel at the organizational level.

The head of the Design and Engineering Department requested that research be conducted regarding maintenance costs and the investment in range test facilities maintained at PMTC. It was decided to investigate maintenance costs from the perspective of controllability of costs over the life cycle of systems/equipment maintained. This approach was pursued because of the severe budgetary and labor constraints within which the DLM program at PMTC must operate. Additionally, it is felt that DLM management does not excercise sufficient influence over many factors which impact on maintenance costs. These factors debilitate DLM

management's ability to effectively utilize and efficiently employ its resources toward the goal of reducing the obsolete condition of PMTC technical equipment.

B. OBJECTIVES

The objectives of this research are:

1. To consider methods of improving maintenance cost control over the life of range systems and equipment.
2. To review the need for life-cycle costing and integrated logistic support analysis during the development of range systems and equipment.
3. To discuss methods of improving the presentation of financial information to DLM management for decision making purposes.
4. To consider areas for expanding DLM management's role in cost control which would enhance cost control and improve the maintenance function.

C. THESIS PLAN

Research into maintenance cost controllability at PMTC revealed that three specific areas required review. These are: life-cycle costing and integrated logistic support theory; industrial maintenance management objectives, policies, measures and indicators of performance; and, DOD funding/financial management policies.

Research was accomplished by first conducting an extensive literature search. The areas of life-cycle costing, integrated logistic support, maintenance management and financial management were scrutinized. A second search was conducted to review DOD reports, instructions and

policies that are relevant to the subject. Finally, on-site visits were made to gain familiarity with the operation at PMTC and to interview key executives throughout the organization.

D. THESIS OUTLINE

The second chapter will provide background information to support subsequent chapters. First, a brief history of PMTC will be traced. This will include a description of the base, its mission and organization. The theories of life-cycle costing and integrated logistic support will be discussed. Pertinent instructions/policies regarding life-cycle costing, integrated logistic support and PMTC's local application of these instructions will be included. Chapter 3 reviews DOD funding policies for Major Range and Test Facility Bases. Considered of importance are: the objectives of the Uniform Funding Policy; the requirement of institutional funding for the Major Range and Test Facility Base; and, the funding of equipment replacement. Chapter 4 deals with industrial maintenance management. Specifically, the objectives, policies, performance measurement, cost control techniques and methods of accounting for maintenance costs will be discussed. Chapter 5 provides an overview of the Navy Industrial Fund, financial management and financial reporting at PMTC. Chapter 6 furnishes conclusions of the research, and chapter 7 supplies recommendations and delineates areas of recommended future study.

II. BACKGROUND

A. PACIFIC MISSILE TEST CENTER

The Pacific Missile Test Center (PMTC) is the Navy's center for test and evaluation of Navy airborne weapons and weapon systems and for support to the fleet in maintaining its in-service weapons systems. This includes an extensive inventory of test and evaluation facilities and equipment, vast ocean areas for range testing and a technical workforce to provide the necessary test and evaluation support in the acquisition of new and improved weapon systems.

PMTC had its inception in 1946 when the Naval Air Missile Test Center (NAMTC) was commissioned at Point Mugu. The location was chosen for its terrain, weather, availability of air and sea space for missile testing and the availability of instrumentation sites on offshore islands.

In 1948, a growth period began which included construction of laboratory, range and support facilities. A separate Naval Air Station was provided in 1949 to provide airfield and base support. As missiles and testing grew in sophistication, so did the facilities and instrumentation of NAMTC.

In 1958, NAMTC was designated one of the six national ranges that would be managed by DOD. NAMTC was recommissioned as the Pacific Missile Range and in 1959 the

Naval Missile Center was commissioned as a separate activity. The Naval Missile Center (NMC) became the Navy's primary organization for test and evaluation of air-launched missiles and weapon systems. NMC played a significant role in the development of the Sidewinder, Sparrow III and Phoenix Missiles.

On April 25, 1975 the Pacific Missile Range, Naval Missile Center and Naval Air Station were consolidated under one command, the Pacific Missile Test Center. The center is located on 4600 acres along the seacoast approximately 50 miles northwest of Los Angeles. A deep ocean area extending about 200 miles to the southwest is used as a sea test range. The area (shown in figure 1) is conveniently accessible to the Pacific Fleet.

Today, PMTC plays an active role in the development and deployment of such weapon systems as "Tomahawk," "Harpoon," "F-14/Phoenix," and "Aegis." PMTC is presently developing support systems for support of Trident operations. The mission of PMTC is to:

> "Perform development test and evaluation, development support, and follow-on engineering, to provide logistics and training support for Naval weapons, weapon systems and related devices, and to provide major range, technical and base support for fleet uses and other Department of Defense and Government agencies."[3]

The center's work includes Navy technical evaluation, Board of Inspection and Survey (BIS), Production Acceptance Test and Evaluation (PATE), and support of weapon systems production and re-work.

PACIFIC MISSILE TEST CENTER OPERATING AREAS

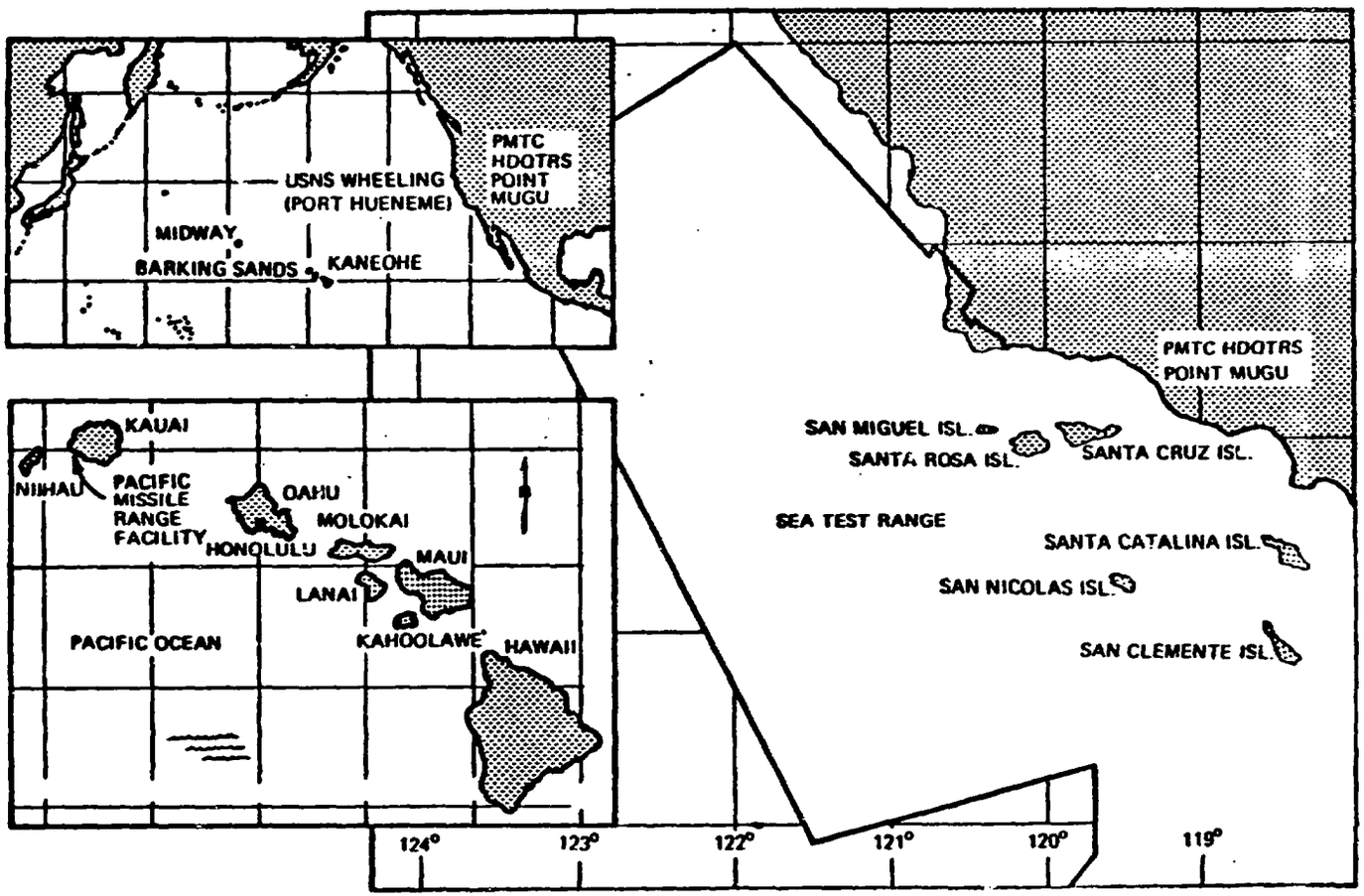


Figure 1

To accomplish its mission, PMTC has a large complement of technical and flight test personnel including pilots, test conductors, engineers, mathematicians, etc. Advanced capability and experience in these fields have been built up through long-term support of weapons development test and evaluation. Approximately 6200 personnel are employed by PMTC.

A highly technical workforce is required due to the demanding range system which is necessary to perform the development, test and evaluation of airborne weapons and weapon systems at PMTC. Figure 2 illustrates the interrelationships of the radar, telemetry, communications, command/control, computers, recording, antennas, cryptographic and related equipment which comprise the complex range system. Critical issues which affect the size and capability of PMTC's labor force are considered in Appendix A.

PMTC is organized as a matrix management system. The organization as it exists at PMTC is displayed in figure 3. The matrix structure of the organization is beneficial because it promotes flexibility. This is a necessary ingredient in a technical organization such as PMTC insofar as it enables specialists such as scientists and engineers to work on sophisticated projects or programs. Additionally, the matrix structure recognizes the competing

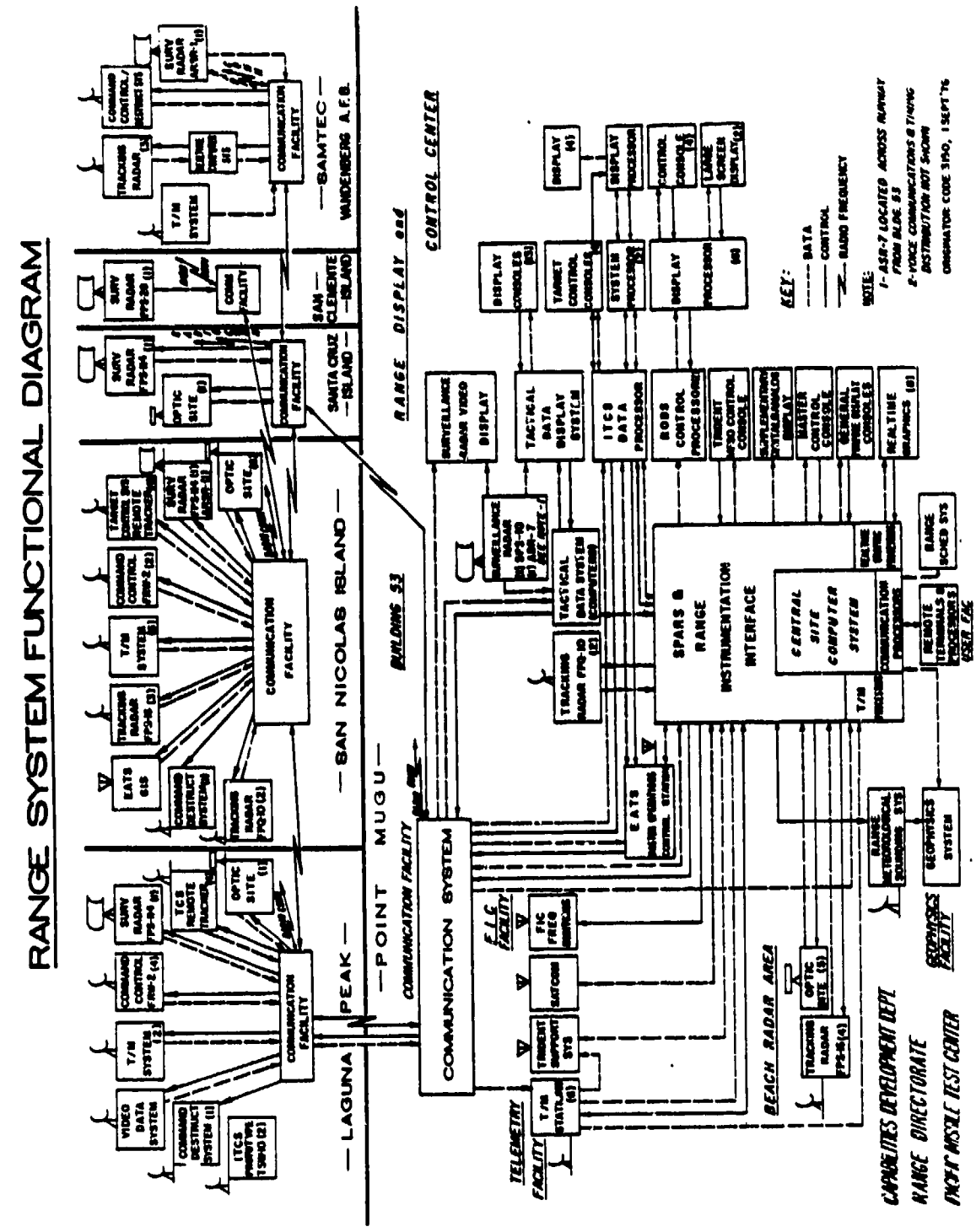
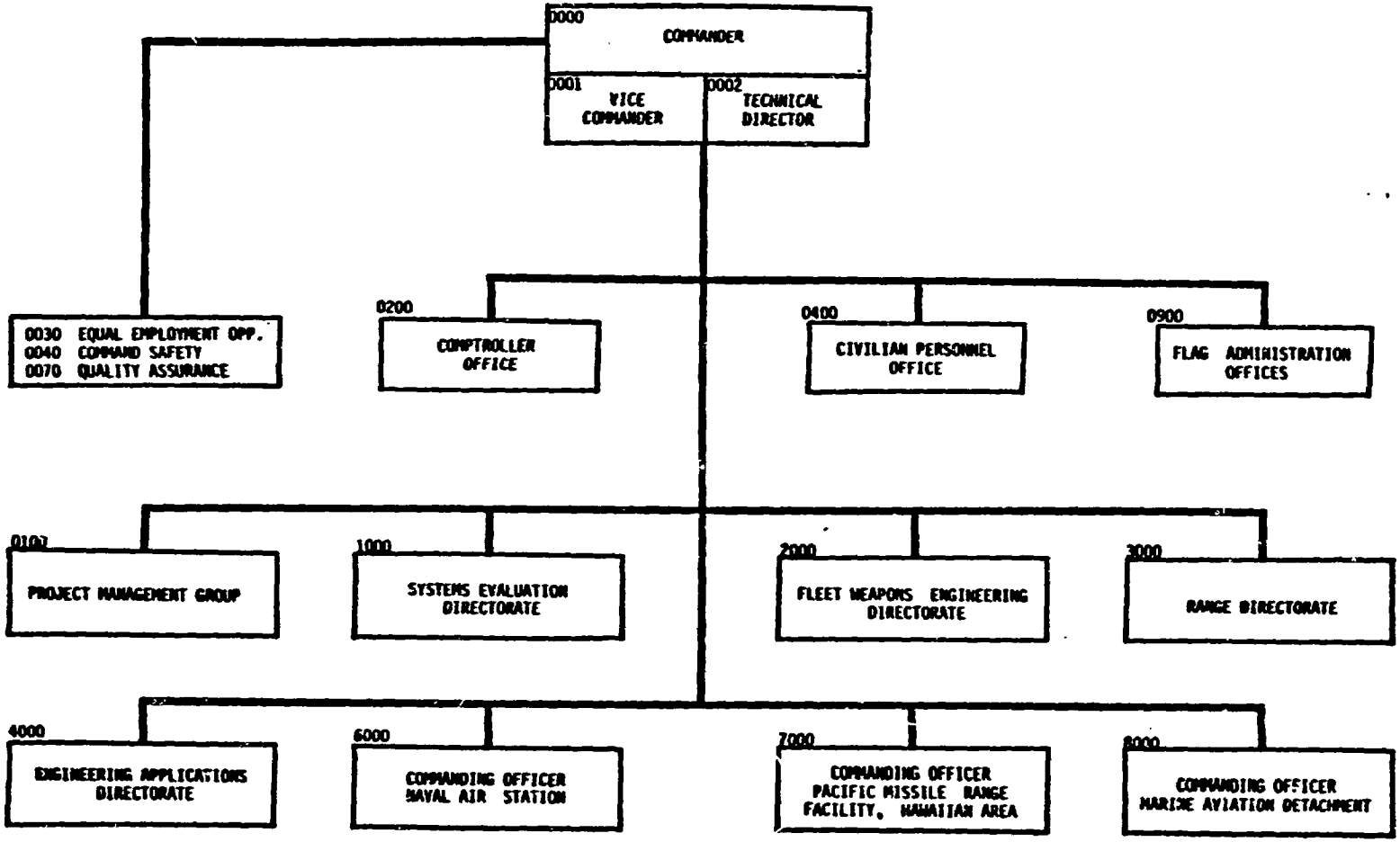

RANGE SYSTEM FUNCTIONAL DIAGRAM
—LAGUNA PEAK— —POINT MUGU— —SAN NICOLAS ISLAND—
—SAMTEC— VANDENBERG A.F.B.
SAN CLEMENTE ISLAND
SANTA CRUZ ISLAND
COMMUNICATION FACILITY
COMMUNICATION SYSTEM
RANGE DISPLAY and CONTROL CENTER
BUILDING 51
SPARS & RANGE INSTRUMENTATION INTERFACE
CENTRAL SITE COMPUTER SYSTEM
TACTICAL DATA DISPLAY SYSTEM
ITCS DATA PROCESSOR
BOSS CONTROL PROCESSOR
SURVEILLANCE RADAR VIDEO DISPLAY
TACTICAL DATA SYSTEM (COMPUTERS)
REMOTE TERMINALS & PROCESSORS
REAL TIME GRAPHICS
RANGE SCHED SYS
RANGE METEOROLOGICAL SOUNDING SYS
GEOPHYSICS SYSTEM
GEOPHYSICS FACILITY
BEACH RADAR AREA
TELEMETRY FACILITY
E.L.C. FACILITY
CARNEGIE DEVELOPMENT DEPT
RANGE DIRECTORATE
POINT MUGU TEST CENTER
KEY:
DATA
CONTROL
RADIO FREQUENCY
NOTE:
1- ASR-7 LOCATED ACROSS RUNWAY FROM BLDG 51
2- VOICE COMMUNICATIONS & TIMING DISTRIBUTION NOT SHOWN
ORIGINATOR CODE 3150, 15 SEPT 76

Figure 2

PACIFIC MISSILE TEST CENTER ORGANIZATIONAL CHART



ACTIVITY	APPROVED	DATE	PREPARED BY	CHART NO.
PACIFIC MISSILE TEST CENTER, POINT MUGU, CALIFORNIA	J C Treanor, COMMANDER, PMTC	15 NOV 1978	MANAGEMENT ANALYSIS DIVISION	0000

11BD-PMTC-5400/1 (Rev. 9-75)

Figure 3

provide depot-level maintenance for range systems, instrumentation and related equipment. The Design and Engineering Department of the EAD is important for this purpose. It is their responsibility to assure and maintain operational readiness of the range and laboratory test facilities. This is accomplished by the development, management and direction of the Depot-Level Maintenance Program for range systems. The Depot-Level Maintenance (DLM) Program for range systems falls under the cognizance of the Inservice Engineering Division of the Design and Engineering Department. They are tasked with the direction of the PMTC DLM program and the operation of a facility to repair and modify radar, telemetry, communication, command control and computer peripheral equipment and related systems. Additionally, the Inservice Engineering Division provides consultation services in integrated logistic support planning, life cycle economic planning and maintainability engineering.

The Comptroller Office is responsible for developing, directing and maintaining an integrated financial management program, system and operation. Inherent in these responsibilities are provisions for planning, programming and budgeting and the provision of financial and accounting services to all internal and external organizations as required. Organizations important for this purpose within the Comptroller Office are the Plans and Budget Division and the Accounting Division.

B. LIFE CYCLE COSTING/INTEGRATED LOGISTICS SUPPORT

The Pacific Missile Test Center plays an important role in the acquisition of major airborne weapons and weapon systems. Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E) are the primary functions PMTC provides in the system acquisition process. DT&E is conducted to demonstrate that the engineering design and development process is complete and to demonstrate that design risks have been minimized and that the system will meet desired objectives when introduced. Similary, OT&E is conducted to estimate the prospective system's military utility, operational effectiveness, operational suitability and to determine any need for modifications.[4]

The Major Systems Acquisition Process is reviewed in Appendix B. The purpose for this review is not for discussion of PMTC's role in that process but rather to briefly review the methodologies employed. Important for this purpose are those elements of the systems acquisition process which relate to maintenance and logistic support of those systems being acquired. Primarily, the areas of Life Cycle Costing (LCC) and Integrated Logistics Support (ILS) will be considered. The major systems acquisition process emphasizing LCC and ILS will then be analyzed for application in the acquisition of test range systems and equipment at PMTC.

Integrated Logistic Support is a composite of all of the support considerations necessary to assure the effective and economical support of systems/equipment for their life cycle. It is an integral part of the system/equipment acquisition process. Similarly, life cycle costing is an acquisition costing technique which considers operating costs, maintenance costs and other costs of ownership in addition to acquisition cost when considering procurement of alternative systems or equipment.[5]

The Department of Defense recognized the importance of ILS in the acquisition of defense systems and equipment. It was realized that availability of a system or equipment was directly related to the reliability, maintainability and effectiveness of its support system in the operational environment. Again, the cost of ownership became a highly important consideration of a system through its entire life cycle. It became necessary to determine an optimum balance between system performance and the system's life cycle cost of ownership. This optimum balance can only be achieved by including logistic support considerations in all stages from the formulation and validation of the system design concept, through engineering design and development, test and evaluation, production, deployment and operation.[6]

It has long been realized that "Over the life cycle of a system, support represents a major portion of the total cost, and is sometimes the principal cost item."[7] Lack

of application of ILS disciplines as an integral part of system development and equipment modification has resulted in insufficient funds being budgeted for logistics support of Navy systems during initial phases of acquisition and equipment modification processes. This has given rise to the operational introduction of systems and equipments with less than full logistic support. The end result is reduced or impaired system/equipment availability.

Support problems limit the operational capability and availability of systems and equipment. It is necessary to be concerned with the definition, implementation and management of logistic support resources throughout the system life cycle. The principal elements of ILS which relate to the overall system life cycle include:

The Maintenance Plan
Support and Test Equipment
Supply Support
Transportation and Handling
Facilities
Personnel and Training
Logistic Support Resource Funds
Logistic Support Management Information

It is necessary to tailor the magnitude, scope and level of ILS analysis and design effort to each system or equipment modification. Elements essential to each program are:

Analysis and definition of quantitative and qualitative logistic support requirements.

Prediction of logistic support costs in funds and other resources.

Evaluation and tradeoffs.[7]

The maintenance plan provides the basis for establishment of supportability requirements in system/equipment design. It delineates maintenance support levels, repair policies and effectiveness measures. Additionally, the maintenance plan complemented by logistics support analysis, identifies maintenance tasks, task frequency and time requirements, personnel quantity and skill requirements, test and support equipment requirements, spare/repair parts requirements, facilities and other resource requirements. Similarly, the maintenance plan affects supply policies and maintenance training programs.

The maintenance plan is regarded as extremely important because of the far reaching influence it has over lesser requirements. Therefore, it is necessary that the maintenance plan be defined prior to the start of equipment design. If development of the maintenance plan is not considered at this stage system components may reflect different design approaches (lack of standardization) and support elements may be incompatible.[8]

Life cycle costing (LCC), as defined earlier, is an acquisition costing technique which considers operating, maintenance and other costs of ownership in addition to

acquisition cost when considering procurement of alternative systems or equipment. The objective of LCC is to insure that the system/equipment procured will result in the lowest overall cost of ownership. Costs associated with system/equipment life cycle which should be included are:

Research and Development

Investment

Operation and Maintenance

System Phase Out

As illustrated in figure 4, all of these costs play a major role in the total system cost during its lifetime.

Life cycle costing has six primary uses. They are:

Long range planning and budgeting

Comparison of competing programs

Comparison of logistics concepts

Decisions about the replacement of aging equipment

Control over an ongoing program

Selection among competing contractors

Each of these uses will be briefly discussed.

Long range planning and budgeting is enhanced by an orderly process. LCC provides an orderly methodology. Estimates derived from LCC reveal possible alternatives and provide a quantitative discipline for evaluating those alternatives. Additionally, these estimates force management to clarify maintenance plans or program operations.

LIFE CYCLE OF A SYSTEM

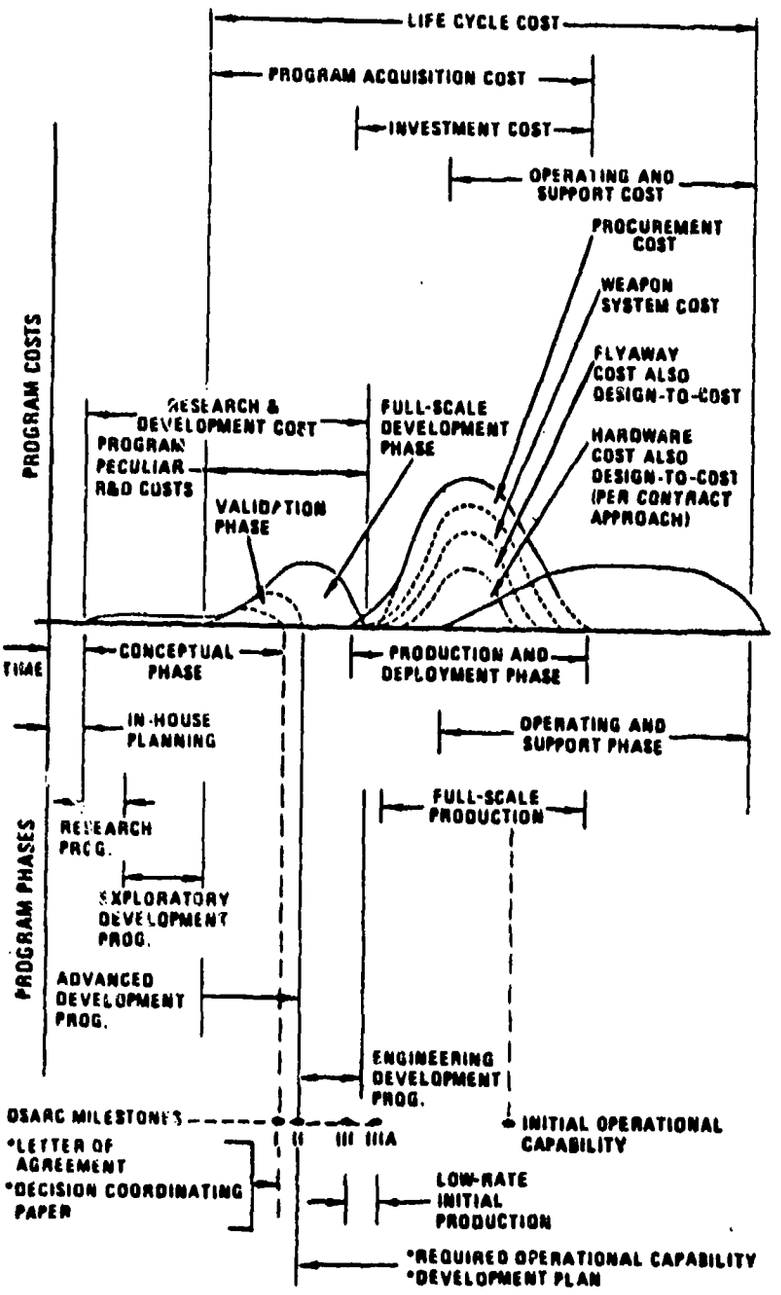


Figure 4

LCC enables the comparison of costs of competing programs. This provides a realistic approach to the final selection of a system or equipment from a number of methods of meeting an operational requirement. Similarly, LCC provides a method of comparing costs of various approaches to logistic support of a system. LCC broadens the analysis of logistic support from one individual operation to entire system support throughout its lifetime.

LCC provides a sound method for reaching equipment replacement decisions. A thorough cost analysis will reveal the inadequacy of retaining aging, inefficient equipment whose worth is well overshadowed by maintenance costs. Similarly, equipment replacement which is desired solely due to fascination with exotic technology will be labeled inadvisable.

LCC may be used as decision criteria as a program progresses through various phases of its life. Through utilization of devices such as design to cost, reliability improvement warranties and others, cost control can be effected as system life progresses.

Finally, the most frequent use of LCC has been as criterion for the selection of a contractor to develop and produce a major weapon system. Of importance prior to contractor selection is the ability to define explicit performance requirements. Similarly, it must be determined if the system/equipment life will be long enough to make an

LCC analysis cost effective and if sufficient historical data exists to permit a reasonable analysis. Then, it must be established if the management resources required to conduct a viable LCC analysis are available.[9]

Advocates of LCC encounter two major problem areas which warrant discussion. The first problem involves the Congressional appropriation of funds. Congress votes separate appropriations for procurement funds and for operation and maintenance funds. Thus, the administration of procurement funds has been separated from the administration of operation and maintenance funds. The result of this is disincentive for a procurement organization to pay a higher price for a system in order to reduce subsequent costs for operation and maintenance. Although this violates the original Congressional intent of controlling expenditures by specifying use of appropriated funds, it can be circumvented by reprogramming funds. It is felt that as more agencies employ LCC techniques and demonstrate to Congress the logic and conclusions of such methods, flexibility to reprogram funds will be become evident.[9]

The second problem encountered by advocates of LCC is the political objection to front end loading. Front end loading results from increased costs of research, development and production in order to achieve later economies in operation and support. Often, immediate budget constraints exert a much stronger influence on politicians than

anticipated cost savings in the future. Congress believes that public opinion is based on present performance as opposed to benefits to be derived from long-range planning.[9]

Thus far, the discussion of ILS and LCC has dealt with the acquisition of major systems. It is realized that the acquisition of most systems and equipment for use at PMTC do not fall into the major system category. Therefore, it is necessary to consider the concepts of ILS and LCC as they apply to systems which are categorized as less than major or as applied to modification programs of existing systems/ equipment.

Appendix C is an excerpt from the Implementation Guide for DOD Systems and Equipments. It provides a list of important considerations in planning ILS tasks for less than major acquisitions. The basic ILS and LCC principles previously discussed are applicable to less than major acquisitions or to system modification programs. However, the method and depth of application is a function of the type of system/equipment acquired (ie. off-the-shelf items) or to the extent of modification and the amount of development involved.

The ILS prerequisite of a major system for entry into production is verification ". . . that the support system will permit operation and support of the equipment system within the resources planned for that purpose." In the absence of formal concept formulation and validation,

preliminary work must be performed in order to determine the scope of the development phase. This involves the accomplishment of task-oriented prerequisites such as:

Definition of requirements for built-in-test capability

Definition of required system maintenance characteristics

Definition of required system reliability

Definition of baseline maintenance plan

Actual tasks which must be accomplished to achieve the conceptual equivalent will be determined by the complexity of system support and the extent of existing support capability. As a minimum, support planning must be sufficient to enable specification of required support parameters and establishment of a baseline support concept.

Acquisition of off-the-shelf items requires that necessary support requirements are available and capable of supporting the system. Of importance in acquisition of off-the-shelf items is the determination of life cycle cost, utilization of existing support capability and compatibility with existing support concepts and maintenance policies.

Off-the-shelf items provide little or no opportunity for influencing the support characteristics of the item. Therefore, the existing support system must be flexible and allow for modification. It is paramount that acquisition of off-the-shelf items include acquisition of required

support capability. This requires a survey of existing capability to eliminate duplication and prevent oversights.

Interviews were conducted to determine the extent of application of ILS and LCC techniques at PMTC. For purposes of comparison, two different areas were examined. The first area to be considered deals with acquisition/ modification of systems/equipment for range test and evaluation at PMTC. The second area considered deals with support and maintenance of fleet weapons.

ILS and LCC techniques are applied on systems acquired or modified for range test and evaluation use. However, due to budgetary constraints and manpower limitations application of these techniques is usually limited to very large systems where such techniques are required for budget justifications. Desire was expressed to apply ILS and LCC for all acquisitions/modifications requiring expenditures of $1 million or greater. An additional problem is that the analysis for lesser expenditures would be cost prohibitive.

The primary criteria considered when developing, modifying or acquiring new range systems/equipment was discussed. In order of priority, these criteria are:

Technical performance

Integration into the range system

Budgetary constraints

Operation and maintainability

Again, these criteria were prefaced with the realization that budgetary and time constraints can often be the over-riding factors in range system development. Although long-term maintenance costs were considered important, reality precluded their consideration as being of primary importance.

It was determined from the interview that interface and exahange of ideas between the design and development organization and the maintenance organization existed but not to a satisfactory degree. The purpose of such interface would be to employ the expertise and lessons learned by the maintenance organization early in the range system development process. It was noted that designed-in-maintenance is important in range system development at PMTC. Additionally, it was felt that the engineers participating in range systems development had a good feel for future maintainability requirements.

An organization tasked with supporting fleet weapons was also queried. The purpose was to gain insight into techniques employed for support of major systems such as the Sparrow, Sidewinder and Phoenix missiles. It was determined that ILS and LCC were well-known techniques for supporting fleet weapons.

Although LCC and ILS techniques are employed, the executive interviewed felt room for improvement existed. This was the result of the opinion that no weapon system

had received a full LCC analysis. The primary reason for this opinion was that various mission scenarios were not examined in adequate detail.

Computer models and algorithms were employed in application of ILS and LCC techniques. However, it was expressed that such models were applied for periods too short to be of much benefit. Usually, such systems evaluation models were employed for a period of 4 to 5 quarters which was regarded as too short.

Logistics considerations play an important role in the support of fleet weapons. Checklists are considered invaluable when considering logistic support requirements. The maintenance plan for supporting fleet weapons is developed during the acquisition cycle. Direct support for all deployed weapons is provided by the Naval Air Systems Command in the form of a technical operating budget.

As demonstrated, LCC and ILS techniques are applied in varying degrees at PMTC. One organization acknowledges their existence, but as a rule does not employ them unless required. Another organization utilizes the concepts conscientiously. Although, utilization of these techniques for major systems is a stated DOD requirement.

It is necessary to consider the applicability of ILS and LCC regarding test range equipment or less than major systems. It is believed that a standardized analytical

package for evaluating life cycle costs and support requirements for range test and evaluation systems would provide great benefits. It must be remembered that the cost of analysis could soon outweigh the system cost. However, brief investigation into support requirements and anticipated system lifetime costs could alleviate numerous future difficulties. A standardized checklist may be adequate. Brief brainstorming meetings between the design and development organization and the maintenance organization could result in the reduction of future costs.

III. DOD FUNDING POLICIES FOR MAJOR RANGE TEST FACILITY BASES

A. UNIFORM FUNDING POLICY

The present funding policy regarding Major Range and Test Facility Bases (MRTFB) plays an important role in the ability to acquire systems/equipment and maintain existing systems/equipment. Therefore, a brief history of the events leading to the establishment of the existing funding policy will be sketched. Then, the objectives of the policy will be stated. A discussion of implications and possible ramifications will follow.

During a Blue Ribbon Defense Panel study of the Department of Defense (DOD) a research staff made a study of Operational Testing and Evaluation (OT&E). It was decided that OT&E merited specific attention because of increasing attention given to OT&E in the weapon system acquisition process. The objectives of the OT&E study were to assess the effectiveness of the organization for and the conduct of OT&E throughout DOD. Additionally, it was necessary to determine whether changes were required regarding policies for the conduct of OT&E or weapons, systems and supporting systems and equipment.

In July, 1970, a "Staff Report on Operational Test and Evaluation" was presented to the President and the

Secretary of Defense by the Blue Ribbon Defense Panel. The major conclusions of significance included in the report were:

1. OT&E is not adequately managed or supervised at OSD level.
2. There should be a specific and substantial OT&E budget to allocate for the most needed OT&E or to augment Service OT&E budgets to obtain data required for high-level studies or decision makers.
3. Conduct of needed OT&E is being adversely affected by inadequate funding and particularly by the lack of budgetary identity for OT&E funds.[10]

In October, 1971, the Deputy Secretary of Defense directed that the Assistant Secretary of Defense (Comptroller) in conjunction with the Military Departments, Director of Defense Research and Engineering and the Assistant Secretary of Defense (Installations and Logistics) examine the application of funding policy at the 26 major test and evaluation activities. A Study Group was formed to review current funding policy, examine the strengths and weaknesses associated with alternative funding methods and to recommend revisions of current policies which would achieve more uniformity and encourage greater inter-service and joint use of limited Defense resources available to support test and evaluation.[11]

The two basic issues addressed by the Study Group were:

Should there be a uniform funding policy for the major T&E support activities?

Should users of T&E support activities pay for services or should the funds for these T&E activities be provided directly through the chain of command to finance the institution providing the service?

Early in the study it was determined that neither full user funding nor full institutional funding would be feasible on a uniform basis for all 26 activities. The Study Group decided on a compromise between institutional and user funding.

Findings of the Study Group lead to this compromise. Through interviews with T&E management and review of existing directives large variations in funding policies and practices among T&E activities were discovered. Similarly, each activity was unique with respect to organization, management, geographical location, mission and facility size. The Study Group concluded that given the above organizational differences the best way to achieve a uniform funding arrangement would be to require users or T&E support facilities to provide funds to pay for only the direct costs of the support provided.[11] Thus, user funding would be provided for direct costs and institutional funding for indirect costs.

Arguments still exist as to which funding policy is more appropriate. Managers of T&E support activities generally prefer institutional funding. However, those who have learned to operate under a user funding system

generally prefer that system. Proponents of institutional funding provide the following reasons as justification for their position:

1. Costs do not vary as function of workload.
2. Reliance on user funds would compromise independence.
3. User funding discourages testing.
4. User funding created administrative difficulties.
5. Difficulties exist in predicting workload.
6. Last-minute cancellations and delays which characterize T&E could cause severe financial problems.
7. User funding would cause erratic budget fluctuations which are not conducive to maintenance of an adequate T&E base.

This reflects fears of financial instability under a system of user funding.

Advocates of user funding rebut these arguments and offer successful operation of several T&E activities under a system of user funding as evidence of its soundness. Additionally, they cite the following:

1. User funding encourages cost consciousness.
2. User funding greatly improves communication between support activities and their customers.
3. User funding supports present DOD program management practices.
4. User funding highlights overcapacity.
5. Under institutional funding high priority projects tend to monopolize test facilities.

Finally, some activities which operate under an industrial

fund with full user funding consider the new funding policy as a major step backward in the evolution of financial management systems.[12]

In June of 1974, Department of Defense Directive 3200.11 entitled "User, Management and Operation of Department of Defense Major Ranges and Test Facilities" was promulgated. The Directive was applicable to the Office of the Secretary of Defense (OSD), Joint Chiefs of Staff (JCS), Military Departments and Specified Commands. The objective of the Directive was to:

> ". . . insure provision of effective test and operational support by facilitating joint use of the MRTFB, by consolidating and standardizing management responsibility at appropriate levels and by setting forth uniform operating guidelines."

Thus, the Defense policy for use, management and operation of the MRTFB was established.

The Directive also established the funding and reimbursement policies which have come to be known as the Uniform Funding Policy. The funding of the MRTFB was designed to assure the most effective development and testing of materials. Specifically delineated were the requirements for a job order costing system and an effective system of cost accounting to be utilized in determining charges under interservice/interagency agreements.[13]

Major ranges and test facilities will be funded in a uniform manner. Reimbursement for use of the ranges and

test facilities by DOD components will be for direct costs only excluding military labor. All other Federal Government Agencies will reimburse for full costs excluding military retirement, depreciation and the unfunded portion of civilian retirement. For purposes of definition, direct costs are all costs which can be identified specifically with a particular program. These costs include direct labor, direct material, minor construction required by the task and other resources maintained for that particular purpose. Full costs are the total of all direct and indirect costs attributable to a product or service. Indirect costs, then, are those costs which cannot be directly identified with a single program. These costs include a proportionate share of management and supervision, utilities and communications, equipment and property rental, maintenance and depreciation of property and equipment.

Costs will be assigned to a program or project based upon a beneficial or a causal relationship which is applied on a consistent basis. Direct costs require specific identification to a job or function served. Indirect costs will be screened into homogeneous cost pools having the same relationship to the jobs or functions served. These costs are then allocated on a basis which best measures the relationship between the indirect cost pool and the jobs/functions.[13] Further review of cost accounting will be accomplished in Chapter IV.

B. INSTITUTIONAL FUNDING

On October 1, 1976 PMTC was chartered to operate as an industrially funded activity. PMTC now operates within the structures and procedures of the Navy Industrial Fund (NIF), which is a revolving working capital fund. As work is accomplished customers are charged full costs which includes overhead. However, because certain cost centers are part of the DOD Major Range and Test Facility Base (MRTFB) and operate under the rules of the Uniform Funding Policy for major ranges and test facilities, there is an exception to the NIF rule of total cost recovery from customers. Under this policy, MRTFB cost centers may charge customers direct costs only. The overhead expense associated with the MRTFB cost centers is funded institutionally by the Naval Air Systems Command (NAVAIRSYSCOM) under program element 65864N.[14] The cost centers which are members of the National Range and are funded by National Range funds (MRTFB institutional funds) must be separately identified for application of MRTFB budget and funding policies.

After analysis of various budget models, a classification of cost centers was made which would provide the most equitable distribution of costs while retaining functional separation. In September of 1975, the PMTC Command and Executive Board approved the classification of the PMTC organization between Engineering/Evaluation and Range/Test

cost centers. The Range/Test cost centers comprise the National Range (MRTFB) while the Engineering/Evaluation cost centers are responsible for development, test and evaluation. A list of authorized PMTC cost centers is provided in figure 5.

Cost centers at PMTC are also divided into direct, general and service cost centers. Direct cost centers are those organizational units which directly perform the technical or productive mission of the activity. PMTC's local definition of a direct cost center is one which can identify 50% or more of its effort to direct projects. General cost centers include those which perform overall support services to the entire activity. Locally, if less than 50% of a cost center's effort can be identified to direct projects, the cost center is classified as a general cost center. Examples of general cost centers at PMTC would include the Command and Staff, Public Works, Supply and most Naval Air Station activities. A service cost center is a subdivision of an activity engaged in the performance of functions which can be readily identified to a test or measurable event and totally costed to users/customers by means of predetermined rates. Overhead costs may be transferred into a service cost center from a direct or general cost center. However, service cost center overhead will not be distributed by cost transfers. All

PMTC COST CENTERS

LIST OF AUTHORIZED PMTC COST CENTERS — FY-1979

C.C CODE	W.C. CODE	ORGANIZATION UNIT	GENERAL	ENG/EVAL DIRECT	ENG/EVAL SERVICE	RANGE/TEST DIRECT	RANGE/TEST SERVICE
00	0AXX	Command & Staff	X				
	0BXX	EEO Office	X				
	0CXX	Command Safety Office	X				
01	01XX	Project Management Group	X				
02	02XX	Comptroller Office	X				
04	04XX	Civilian Personnel Office	X				
07	07XX	Quality Assurance	X				
09	09XX	Flag Admin. Office	X				
10	10XX	SED Director & Resource Office		X			
11	11XX	Weapon Sys. Test Dept.		X			
12	12XX	Systems Technology Dept.		X			
20	2XXX	Fleet Wpns. Engr. Dir.		X			
	21XX	Sys. Engr. Dept.		X			
	22XX	Supt. Engr. Dept.		X			
	23XX	Fleet Wpns. Tech. Reps.		X			
30	3XXX	Range Director & Resource Office				X	
31	31XX	Capabilities Develop. Dept.				X	
32	32XX	Range Operations				X	
3B 1/	3BXX	Range Operations Services					X
3C 1/	3CXX	Range Instrumentation Serv.					X
33	33XX	Threat Simulation Dept.				X	
3P	3PXX	Target Presentations					X
34	34XX	Range Instrumentation Sys. Dept.				X	
36	36XX	Range Mgmt. & Safety Ofc.				X	
40	40XX	EAD Directorate & Staff				X	
41	41XX	Design & Fabrication Dept.				X	
42	42XX	Photo & Tech. Info. Dept.				X	
60	60XX	NAS CO and Staff	X				
61	61XX	Air Operations Dept.				X	
62	62XX	Public Works Dept.	X				
6H	6HXX	P.W. Family Housing		X			
63	63XX	Supply Dept.	X				
64	64XX	SNI Department				X	
65	65XX	Security Department	X				
67	67XX	Aircraft Maint. Dept.				X	
68	68XX	NAS Administration Dept.	X				
70	70XX	PMRFACHAWAREA, Range Serv. Dept.				X	
73	73XX	PMRFACHAWAREA, Range Oper. Dept.				X	
80	80XX	Marine Aviation Det.	X				

Figure 5

service cost centers operating under the Uniform Funding Policy will charge overhead to the institutional fund as it occurs.

Budget development at PMTC entails the formal determination of the funds required to procure the labor, material and other services required to accomplish the Command's objectives and fulfill the activities for the coming year. Although a NIF activity, only one budget call is issued. MRTFB budget data (institutional) is extracted from cost center responses to that budget call. The Budget and Finance Division compiles the cost center responses and prepares the following three budgets:

NIF Operating Budget

NIF A-11 Budget

MRTFB (institutional) Budget

The NIF and MRTFB budgets are distinct.

The MRTFB budget is an appropriation budget and as such its preparation is separate from the NIF budget. The NIF budgets include MRTFB budget data but the MRTFB budget does not include NIF data because it is prepared for the Range/ Test cost centers only. The MRTFB budget is a funded line item in the DOD Five Year Defense Plan. As such, it is subject to the procedures of the planning, programming and budgeting process.[14]

Budget preparation and analysis at PMTC is a year-round process. The Comptroller's Office issues the

internal budget call in the February time frame. The budget call formally initiates the budget cycle and solicits data from the cost centers. The Budget Division collects cost center data, prepares a consolidated budget and reviews it with the Command. The Command budget is submitted to NAVAIRSYSCOM (AIR-06) in early August. As an appropriation budget, the MRTFB budget must be justified for all levels of funding (minimum, basic, enhanced). Additionally, it is subject to review at all steps in the chain of command and is not free of the Congressional appropriation cycle as is the NIF budget.

As stated in DOD Directive 3200.11, "Use, Management and Operation of Department of Defense Major Ranges and Test Facilities," the MRTFB (institutional) budget is intended to support the following services performed by or provided to Range Test cost centers:

Operation and maintenance of facility instrumentation.

Reduction of data collected by facility instrumentation.

Photography

Transportation

Maintenance and repair of all general purpose facilities and, when established by special agreements, facilities which are unique to particular users.

Utilities

Calibration service.

Review of figure 5 indicates that the Design and

Engineering Department falls under the Range/Test cost center classification. As stated earlier, the Design and Engineering Department is responsible for the Depot-level maintenance program for range systems at PMTC, which entails the majority of the services listed above. Thus, the great majority of DLM is institutionally funded. Also of importance, is the fact that the MRTFB budget must fund new capability procurement such as CCMP, EATS and other improvement and modernization programs in addition to equipment procurement. New capability procurements accounted for 60% of PMTC's FY-80 MRTFB budget, while DLM for the entire PMTC range complex accounted for only 2.8%. Experience indicates that during periods of liberal budgeting, expenditures were made toward equipment procurement and range system improvement. Similarily, during periods of constrained budgets maintenance of systems and equipment suffers first when cost center budget cuts are made.

C. FUNDING EQUIPMENT REPLACEMENT

Recent reductions in appropriated funds for range systems and equipment have created problems for test facility management. Limited funds in conjunction with aging and somewhat obsolete equipment accentuate existing and future difficulties.

The majority of the equipment at PMTC considered for this purpose relates to test and evaluation. This equipment is managed and funded by the Naval Air Systems Command for the instrumentation of range and test facilities. It is considered general purpose equipment in that it supports PMTC's overall mission. Therefore, it is funded through appropriation because of its high cost.

The existing methods of funding equipment replacement are no longer adequate in all regards. Equipment with a purchase price of $5000 or less may be considered as a current annual expense and charged to the overhead account. Equipment purchased by NIF cost centers which demonstrates the ability to produce "real" savings may be financed under the fast payback method. However, this method is limited to acquisitions of expense type items from $1000 to $100,000. Additionally, for these items the savings must at least equal the investment cost and must be realizable within three years.[15] Those cost centers at PMTC which fall under the Major Range and Test Facility Base are prohibited from utilizing the NIF fast pyaback method of acquiring expense type items. The remaining funding method is through appropriation which primarily involved the RDT&E appropriation at PMTC.

The inherent difficulties with the above systems/ equipment funding methods are:

1. Most systems/equipment cost more than $5000 and cannot be considered as a current expense.

2. Range systems/equipment replacement is not applicable to the fast payback method of industrial fund financing.

3. Appropriation funding levels have been insufficient to meet the needs required by aging equipment and increasing technology.

A recent study was conducted to investigate the problems associated with equipment replacement at Navy Industrial Funded RDT&E activities. The hypothesis of the study was that replacement of equipment at NIF RDT&E activities was controlled by the amount of funds available for equipment replacement as opposed to logical management decisions to replace equipment as needed. The premise was that NIF activities should be allowed to depreciate equipment and set up a reserve for replacement of aging equipment. This would bring industrial funded activities more in congruence with industrial practices in the private sector.[16]

The conclusion of the study was that the present methods of acquiring equipment do not conform to accounting and costing practices which exist in the private sector. Therefore, it was recommended that equipment be capitalized. Capitalization would assist in solving the problem of replacing aging equipment at NIF RDT&E activities. Amortization of equipment costs over equipment life would reflect a more accurate value of equipment worth.

Additionally, it would enable the accumulation of funds required to provide for the orderly future replacement of aging equipment.

D. SUMMARY

The Uniform Funding Policy was established to standardize MRTFB management and to insure effective T&E support by setting uniform operating guidelines. The original intent of the policy was to provide equitable service to the users of MRTFB T&E facilities. Although a uniform policy was established, uniform application of that policy was not assured. The policy was shortsighted in that it did not consider long range impacts on MRTFB management. Those impacts are presently being felt.

Existing economic conditions are causing the pinch. The prevailing attitude in Washington is to minimize expenditures. Thus, MRTFB management is being forced to acquire equipment to replace existing aging equipment and to maintain existing equipment with shrinking dollars. The result is budgetary conflict. Although a system of zero-base budgeting is in operation, the MRTFB at PMTC is operating in the traditional incremental budgeting mode.

The budgetary conflict exists not only at the local level but also at the Congressional level. The institutional budget is subject to Congressional review

and open to arbitrary cuts without evaluation of activity needs. At the local level, the decision must be made whether to replace or overhaul/refurbish aging equipment.

Alternative methods of funding equipment replacement are no longer adequate. Capitalization of equipment provides an option that does not presently exist. That option is to amortize equipment costs and establish a reserve for future equipment replacement. This would provide more funds for maintenance and overhaul of operational systems/equipment until eventual replacement becomes feasible.

IV. INDUSTRIAL MAINTENANCE MANAGEMENT

A. MAINTENANCE OBJECTIVES

The purpose of the maintenance function is to enhance the operational effectiveness of the organization. This is accomplished primarily through improving equipment performance or increasing systems/equipment availability. Unfortunately, the maintenance function has often been neglected. In many organizations, both in the private and public sectors, maintenance is considered a necessary evil. Symptoms of this attitude are manifested by:

Excessive machine breakdowns
Frequent emergency work
Domination of maintenance by operations
Lack of equipment replacement programs
Insufficient preventive maintenance
Inadequate maintenance training
Poor shop facilities [17]

It is, however, becoming apparent that the need for maintenance is real and that the neglect of maintenance is being overcome.

Increased attention has been focused on the problems which plague the maintenance of the Navy's shore establishment. Among these is advanced deterioration which threatens readiness in many areas. Limited resources

have forced maintenance and repair programs to revert to a policy of semi-breakdown maintenance. The result of this has been an inaccurate record of total budget requirements for maintenance and repair of real property.

Having affirmed not only the existence of a need for maintenance but the necessity for improved maintenance, it is necessary to consider the primary objectives of the maintenance organization. The principal objectives of maintenance can be defined as follows:

1. To extend the useful life of assets.
2. To assure the optimum availability of installed systems/equipment for operations and to obtain the maximum possible return on investment.
3. To insure operational readiness of all equipment required for emergency use.
4. To insure the safety of the personnel using the systems/equipment.

Perhaps the goal of primary importance to the maintenance organization is to achieve the above objectives as economically as possible on a long-term basis. It is important that the maintenance function be kept in the right perspective. Large organizations are not in business to run elaborate or sophisticated maintenance departments. They must strive to develop a competent and effective maintenance function that will provide the support necessary for operation.

The level of sophistication in maintenance management must be a function of the total needs of the organization.

Elaborate maintenance departments cannot be justified if a net improvement in total organizational effectiveness is not sought. Equally important is the demonstrated ability to generate sizeable cost-savings through efficient, well managed maintenance departments.

Maintenance will be defined for this purpose as, "A combination of any actions carried out to retain an item in, or restore it to an acceptable condition." This definition was quoted from a work dealing with a fairly new maintenance concept conceived in Great Britian. The concept is that of "Terotechnology" which deals with maintenance technology and involves more than maintenance. The concept is defined as follows:

> "Terotechnology is a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economical life cycle costs; it is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings, structures, with their installation, commissioning, maintenance, modification and replacement, and with feedback of information on design, performance and costs."[18]

Terotechnology is very similar to the theories of life cycle costing and integrated logistics support considered in Chapter II. However, an innovative twist has been added. Terotechnology applies the notion of management to life cycle costing. Not only is management concerned with cost reduction during the design of systems but also with cost control and performance monitoring after system

implementation. This is achieved through utilization of ". . . feedback information on design, performance and costs." The ideas of cost control and performance measurement will be more thoroughly considered in a subsequent section.

When considering the objective of a maintenance organization, it is necessary to distinguish between the levels of maintenance necessary for support. Maintenance support levels are usually delineated in the maintenance concept which defines logistic support requirements. For this purpose, the levels of maintenance are Organizational maintenance, Intermediate maintenance and Depot maintenance. Each level will be briefly defined.

Organizational maintenance is performed at the operational site. It includes tasks performed by the using organization on its own equipment. Maintenance at this level is limited to periodic equipment checks, inspections, cleaning, servicing, minor external adjustments and removal and replacement of some components. Removed components are generally not repaired at this level but rather are forwarded to an intermediate level for repair. Personnel assigned at this level are usually the least skilled with regard to equipment maintenance. Thus, equipment to be maintained at the organizational level must account for this degree of skill and should be designed for simplicity in terms of repair.[8]

Intermediate maintenance is performed by mobile, semi-mobile or specialized organizations. Repair at this level usually involves removal and replacement of modules, assemblies or piece parts. The mission of mobile intermediate maintenance is on-site maintenance which is beyond the capability of organizational maintenance to facilitate the return of a system to operational status on an expedited basis. Fixed installations are employed to support both the organizational and mobile units. Maintenance requiring greater skill and more specialized equipment are performed here. Personnel at the intermediate level usually possess greater skills and intermediate level facilities are usually better equipped than the organizational level and are normally responsible for performing more detailed maintenance.

Depot level maintenance constitutes the highest type of maintenance and supports requirements which are greater than the capabilities available at the organizational and intermediate levels. The maintenance depot is normally a specialized repair facility which supports a number of systems/equipment in the inventory. Depot-level maintenance includes the complete overhauling; rebuilding and calibration of equipment as well as numerous highly complex maintenance actions. Figure 6 provides a summary of the three levels of maintenance.

MAJOR LEVELS OF MAINTENANCE

Criteria	*Organizational Maintenance*	*Intermediate Maintenance*		*Depot Maintenance*
Done where?	At the operational site or wherever the prime equipment is located	Mobile or semimobile units	Fixed units	Depot facility
		Truck, van, portable shelter, or equivalent	Fixed field shop	Specialized repair activity, or manufacturer's plant
Done by whom?	System/equipment operating personnel (low maint. skills)	Personnel assigned to mobile, semumobile, or fixed units (intermediate maintenance skills)		Depot facility personnel or manufacturer's production personnel (mix of intermediate fabrications skills and high maintenance skills)
On whose equipment?	Using organization's equipment	Equipment owned by using organization		
Type of work accomplished?	Visual inspection Operational checkout Minor servicing External adjustments Removal and replacement of some components	Detailed inspection and system checkout Major servicing Major equipment repair and modifications Complicated adjustments Limited calibration Overload from organizational level of maintenance		Complicated factory adjustments Complex equipments repairs and modifications Overhaul and rebuild Detailed calibration Supply support Overload from intermediate level of maintenance

Figure 6

Depot level maintenance at PMTC is managed through the Inservice Engineering Division. They provide a facility to repair and modify radar, telemetry, communication, command control, computer peripheral and related systems. Additionally, they operate a facility to test and evaluate antenna systems. The depot-level maintenance program at PMTC is responsible for repair, overhaul and modification of numerous unique and highly complex systems. Thus, advantage cannot be taken of high-volume techniques which utilize assembly lines and relatively unskilled labor.

B. MAINTENANCE POLICIES

The policies adopted by maintenance management are largely a reflection of the attitudes of higher management. If top management is concerned with preservation and availability of systems and equipment, the maintenance function will probably be held in high regard. Otherwise, maintenance management must contend with inadequate funds, limited personnel and will always have to wrestle for operational equipment to initiate repair and corrective action.

Probably the most predominant method of managing maintenance is through unplanned execution of emergency repairs. Under this method, equipment is allowed to fail

before maintenance is applied to correct the fault or repair the damages. The maintenance organization is controlled by the work demand.

Emergency maintenance, although not totally avoidable, is inefficient and results in many hidden costs to the organization. Opportunity costs resulting from interruptions, inoperative equipment and work stoppages are seldom fully evaluated and usually underestimated. Therefore, large organizations which depend upon the availability and performance of equipment endeavor to eliminate unplanned, emergency repairs which result in interruption of operations. This is accomplished through planned or scheduled maintenance.[18]

Administrative control of the maintenance function changes significantly when an organization adopts a policy of planned maintenance. The maintenance system is administered by technically and financially directing and controlling the maintenance operation with the objectives of high maintenance standards and greater cost effectiveness. Successful planned maintenance programs are those which are as simple as possible and involve a minimum amount of paperwork.

A system of planned maintenance may be divided into two phases. These are preventive maintenance and corrective maintenance. Preventive maintenance programs

are instituted because maintenance costs of modern, state of the art systems/equipment are high. Similarly, the cost of system/equipment downtime is also high. No matter to what degree of refinement a preventive maintenance program is developed, all programs contain these activities:

1. Periodic inspection of assets and equipment to uncover conditions leading to breakdowns or harmful depreciation.
2. Upkeep of systems/equipment to avoid such conditions or to adjust or repair them while they are still minor.[19]

A properly conducted preventive maintenance program can result in real savings in maintenance and operating costs. An organization that does not presently employ a preventive maintenance program and desires implementation of such a program must first establish a minimum standard of maintenance. Facilities and equipment that have been allowed to deteriorate because of either a false sense of economy or a pressing operating schedule must be refurbished to the minimum level. System stability must be attained before a preventive maintenance program will be successful.

The major objective of a preventive maintenance program is obviously cost reduction. Cost savings resulting from a preventive maintenance program can be realized through:

1. Reduction of system/equipment downtime.

2. Conservation of assets and increased equipment life expectancy.

3. Reduced overtime costs and more economical employment of maintenance personnel.

4. Fewer large scale repairs.

5. Lower repair costs.

6. Postponement of cash outlays for premature replacement of equipment.

7. Identification of equipment with excessive maintenance costs indicating the need for corrective maintenance, operator training or replacement of obsolescent equipment.

A well-managed and well-planned preventive maintenance program will yield benefits far in excess of its cost.

A preventive maintenance program in and of itself is not a cure all for excessive maintenance costs. Other maintenance functions such as a good paperwork system, work planning and scheduling, work measurement, control reports and good shop facilities must be integrated to achieve an efficient maintenance program.

C. PERFORMANCE MEASUREMENT

Management control is the process through which resources are obtained and used effectively in the accomplishment of an organization's objectives. The objectives of the maintenance organization were previously discussed. Additionally, the benefits of a preventive maintenance program have been reviewed. Preventive maintenance programs require planning, coordinating and control in order to realize those benefits.

The maintenance function employs labor, material, equipment and services to accomplish department objectives. Management control requires that the results of the maintenance function (outputs) be compared with the planned results. Thus, maintenance management must have targets and must know the extent to which they are being met. This requires the ability to plan and control maintenance work and measure results against realistic standards of performance.

One method of measuring performance is in terms of efficiency. Efficiency may be briefly defined as the ratio of outputs to inputs or the amount of output per unit of input. The inputs in the maintenance function, labor, materials, equipment and services can be measured and can be expressed in monetary terms. The outputs of the maintenance function, however, are difficult to measure and are not easily stated in monetary terms. The measurement of benefits resulting from maintenance such as reduced equipment downtime, increased equipment life expectancy, etc. will be subjectively measured at best.

Effectiveness is a measure of performance which relates outputs to objectives. Use of this measure requires that the organization have detailed goals and objectives and a method for comparing planned results with actual results. Since both objectives and outputs are difficult to quantify, measures of effectiveness are rarely employed.

Although efficiency and effectiveness measures are not wholly applicable to the maintenance function, systems of measurement exist that can measure maintenance activity with an adequate degree of accuracy. Such systems of work measurement were conducted on a scientific basis and were pioneered by Frederick W. Taylor and Frank B. Gilbreth in the field of time and method study.

The need for work measuremont in the maintenance field is recognized. All work activities are subject to some degree of control. In order to achieve control, it is necessary to compare actual results with a target or predetermined goal. As operations become less controlled by the process, the need for quantitative goals becomes more significant. This is especially true for the maintenance function.[18]

The primary benefit to be derived from work measurement is increased performance with a corresponding decrease in labor costs. Work measurement and control usually reveals that the labor force is not performing to its full potential. An additional benefit of measurement is a reduction of delays. Delays resulting from material shortages, an inefficient supply system or an incomplete knowledge of work ordered will be recognized and accounted for. A third benefit realized is reduced system/equipment downtime. Work measurement in the area

of maintenance mechanics encourages the development of standards. The use of standards fosters better labor performance which intuitively leads to reduction of equipment downtime.

Performance can usually be measured in terms of man-hours and costs incurred during the maintenance function. This involves both the use of work study and costing procedures for planning and control. Additionally, the use of specific performance indices can be beneficial.

Work study is a family of techniques which can be divided into work measurement (time study) and method (motion) study. Work study is applied across a great many activities involving human work. The goal of work study is to establish a time standard for a given task. This involves prescribing the best method of performing a task and determining the time required for a qualified worker to perform that task under specified conditions. In situations such as an assembly line, time standards can be very precise. However, under other circumstances including maintenance, time standards can only be estimates. Nonetheless, the establishment of estimated standards through a systematic work study enables the maintenance manager to attain a degree of control over maintenance operations.[20]

Briefly, the types of work study or maintenance work measurement programs will be considered. The intent is not to deal with the mechanics of work study techniques. It is realized that there are many detailed considerations and a massive volume of specialist literature available. Rather, it is desired to introduce the techniques for work measurement and control that have been successful in numerous industrial operations.

Job estimating involves an estimate of labor hours required for a maintenance task. These estimates are usually made by a foreman or a planner and are based primarily on previous experience. Time estimates are established for each task and in certain circumstances published data are used as guides in making the time estimates.

Formal planning and maintenance scheduling systems are often based on time estimates. Such schedules are usually based on clerical procedures rather than on an engineering approach. The result of such estimates is usually only slightly improved maintenance and minor improvement in labor utilization.

Estimates have inherent weaknesses and are inconsistent. Each foreman and planner makes estimates differently. Thus, the job estimate is probably the least reliable type

of measurement on which to base maintenance. However, it is the easiest and least cost method to measure maintenance.[18]

Work sampling is a widely-used method of measuring labor effectiveness. It determines the proportion of time spent by one or more persons and related equipment in each component of their work activity. Through a series of random observations, statistical data is gathered for activities occuring in each observation. Amount and causes of idle time as well as the percent of performance of workers while working is recorded. Work sampling can be used to study any type of work. It can assist in the improvement of maintenance work methods as well as in the reduction of idle time. A comparatively inexpensive approach, work sampling offers means for surveying labor utilization. Additionally, it assists in establishing performance standards and controls on material and machine utilization.[21]

Method or motion study is a standardized step-by-step process. It involves the recording of methods for accomplishing a task by the use of flowcharts or symbols. The record is then critically analyzed. Each operation making up the total task is systematically investigated. The result of such analysis is usually the generation of an improved method for accomplishing the task. The new method then undergoes the same critical process.

Once the desired method is established direct or indirect work measurement techniques must be applied. Direct work measurement involves time study, usually by stopwatch. Indirect measurement utilizes estimates already discussed.

The pioneers of scientific management showed that the way toward cost control was through analysis of work into its basic elements. The analysis results in the establishment of standard times which lead to standard job times for planning and control. Performance is based upon results achieved with a level of inputs. The utilization of job standards make comparisons meaningful and provide management with a viable method of controlling operations and a valuable measure of organizational performance.

D. COST CONTROL

Control, as defined earlier, is the process by which management ensures that the organization is conforming to prescribed plans and policies in working toward the attainment of stated objectives. The existence of a control process enables management to know where the organization stands in relation to a predetermined and desirable future position. Cost control, then, is concerned with keeping costs at their planned level. In this manner, costs conform as much as possible with existing standards. In comparison, cost reduction is concerned with establishing

costs at the minimum acceptable level by searching for methods of improving standards which provide the criterion for cost control.[22]

Costs can only be controlled if they are related to the organizational framework. This introduces the concept of responsibility costing. Each manager must know what his responsibilities are and what is expected of him. Only then is it possible for him to plan and control costs. The essence of responsibility costing is a system which is tailored to the organization so that costs can be planned, accumulated, reported and controlled by levels of responsibility within the organization.

The primary purpose of standards in the cost control process is to identify areas of inefficiency, measure the inefficiencies and bring the inefficiencies to the attention of management. Management should then exercise authority and take action necessary to correct the deficiency. Standards can be set for labor, materials and fixed and variable overhead.

Control of maintenance costs presents similar problems and solutions as the control of other costs. One distinguishing feature of maintenance is that in most organizations it is considered an indirect operation unrelated to the primary operation of the organization. However, as equipment increases in sophistication and

specialization more maintenance is required, and the ability of operators to maintain their own equipment is diminished. Additionally, maintenance costs become a proportionately larger portion of the total cost of operations.[23]

There is no need for cost control procedures to be highly sophisticated or elaborate. What is required, quite simply, is basic feedback to maintenance and general management for decision making purposes. It is of little use to know only the amount by which actual performance differed from standard performance. In order to effect cost control through corrective actions, it is necessary to know what factors accounted for the difference. Therefore, the requirement for a utilitarian reporting system exists.

A system of reporting is essential to cost control. It must provide management with the information necessary to fulfill responsibilities. Reports must contain succinct, relevant and useful information. The purpose of such information is to:

Assist management in decision making.

Indicate performance.

Aid management in planning.

Paramount is the requirement that reports provide information for decision making in a timely manner.[22]

A common mistake is the application of inappropriate costing techniques to maintenance activities. A sound practice is to design a special costing system for maintenance especially in those organizations with a large maintenance department. Similarly, it is reasonable to involve maintenance management in the development of a costing system. It is easy to make the costing system the sole domain of the accountant but such strategy is not recommended.

Maintenance management needs to know regularly the status of expenditures in order to effectively modify present strategies and plan future work. A simple system, built upon cost codes, can be established for a planned maintenance program. This system should accumulate costs under the headings of department, facility, type of system or equipment, type of maintenance, materials and labor. The concept of cost collection will be addressed further in the section discussing cost accounting. However, important in the discussion of cost control is the accounting function that should provide regular reports displaying variances between actual and budgeted expenditures for the headings listed above. Briefly, the concept of variance analysis will be reviewed.

Variance analysis, which involves the computation and classification of variances, is vital to standard costing

and cost control. The value of variance analysis lies in the determination of the cause of the variance and acting to correct it. Variances are the differences between actual and standard costs and are therefore only as reliable as the standards. They may be applied to the cost of materials, volume of materials used, cost of labor, efficiency of labor utilization and overhead.

The "volume" variance shows the differences of expenses or revenues attributed to the fact that actual volume differed from budgeted volume. The "price" variance shows the difference between actual and budgeted price for various input factors such as material or labor. This variance may or may not be controlable by management. The "efficiency" variance is residual. It is the amount of variance not explained by the other causes. The efficiency variance is of primary interest to management. The principle reason for identifying the other variances is to segregate them in order to focus attention on the efficiency variance.[24]

Cost control efforts can be aided by using ratio analysis techniques. Ratio analysis is a variation of budgeting and standard costing and tends to deal with broad issues. A common tool of finance, ratios provide a means of highlighting relationships. They are used daily on Wall Street and throughout industry for relative

performance comparisons. Utilization of ratios for maintenance cost control has been somewhat limited. However, maintenance and general management are continually seeking effective indicators to measure maintenance costs and that will reflect efforts to control those costs. Evidently, no single index or indicator is adequate but a combination of indices may serve to meet management's objectives.

Indices should serve two purposes. First, they should indicate improvements or trends of maintenance performance. Second, if possible, they should indicate an absolute position, which is difficult to accomplish. To indicate trends, maintenance performance must be based upon factors of reference which are relatively stable. To be of value, an indicator of absolute position of maintenance must have a base. In industry, comparisons are made between large assembly plants for example. Normally, determination of an index showing the absolute position of maintenance is impossible. Thus, the true purpose of indices is to indicate trends.[18]

Quite frequently maintenance management does not know if its department is doing an effective job. The primary reason for this is that necessary records are not maintained. In view of this, indices are an essential tool of maintenance management as a form of performance

measurement and as an aid in planning and control. Ideally, maintenance ratios would seek to measure aspects of work which are solely dependent on maintenance management policies, strategies and tactics. It is necessary that maintenance indices be credible to general management and that they link maintenance activity to the primary operation of the organization.[20]

There are many indices available for maintenance management to employ. First those indices related to cost will be considered.

$$\frac{\text{Total cost of maintenance}}{\text{Total manhours worked by maintenance employees}}$$

This index provides a maintenance cost in dollars per hour for a given period. The aim is to reduce the index gradually.

$$\frac{\text{Direct cost of emergency repairs (labor and materials)}}{\text{Total direct cost of all maintenance}}$$

This index is useful in assessing the influence of preventive maintenance over time. As preventive maintenance is introduced the index value should decrease. Utilization of these indices must be made with caution. If heavy investments are made in capital equipment or if equipment use increases, this index could change dramatically.

Manhour indices reflect the ability to plan and schedule work. Also, they indicate areas that are

receiving emphasis and focus on full utilization of labor resources. A few common manhour indices are:

$$\frac{\text{Overtime hours worked by maintenance employees}}{\text{Total hours worked by maintenance employees}}$$

$$\frac{\text{Total maintenance manhours on preventive maintenance work}}{\text{Total maintenance hours worked by maintenance employees}}$$

$$\frac{\text{Total maintenance manhours on emergency work}}{\text{Total maintenance hours worked by maintenance employees}}$$

$$\frac{\text{Time recorded on maintenance job cards}}{\text{Total maintenance clock card times}}$$

$$\frac{\text{Total manhours allowed for maintenance work}}{\text{Total actual manhours recorded for the same work}}$$

The above indices provide valuable information regarding the preventive maintenance program, amount of emergency work and volume of overtime.

Industry utilizes indices which relate maintenance expenditures to the value of the investment in plant and equipment maintained. This is done in the following methods:

$$\frac{\text{Total cost of maintenance}}{\text{Total value of plant/equipment maintained}}$$

$$\frac{\text{Total cost of maintenance}}{\text{Total replacement cost of plant/eauipment maintained}}$$

This relationship is widely advocated. However, a problem is that it ignores the usage level of equipment and assumes that inflation can be accounted for over a number of periods.

Another approach is to use indices which relate maintenance to level of operations or operating costs. Industry could use production costs or production time. An organization such as PMTC could use range operating costs or range hours. The following indices are typical:

$$\frac{\text{Production operating time}}{\text{Production operating time + downtime}}$$

or;

$$\frac{\text{Range (system) operating time}}{\text{Range (system) operating time + downtime}}$$

$$\frac{\text{Total direct maintenance manhours}}{\text{Total production manhours}}$$

$$\frac{\text{Total cost of maintenance}}{\text{Total cost of production}}$$

These are only a few examples of indices which are applicable to all maintenance functions. It is realized that they must be used with care because there are often variables which affect their value and which cannot be controlled by maintenance management. However, maintenance management can develop indices which are tailored to its needs. Additionally, the indices can be plotted graphically and indicate trends which otherwise may go unnoticed. Indices are purely information to assist decision makers. They form the basis of a sound control system within the maintenance department.

E. BUDGETING

Budgeting is a management tool for planning and control. A budget is a plan expressed in monetary terms. Historically, budgets have been employed as a method of limiting expenditures. More recently, however, the budget process has been used as a means for obtaining the most productive and profitable use of the organization's resources, via planning and control.

The budgeting process consists of establishing organizational objectives, devising plans and standards for every area of activity, comparing actual results with planned results and taking necessary corrective action.[22] The development of a budget plan must consider all dimensions of the organization. Each activity has an impact on many other activities. Thus, budgeting acts as a communication aid and enables managers to see how their area of activity fits into the whole.

A comprehensive budgeting system consists of three types of budgets: operating, cash and capital budgets. The operating budget is important for this purpose. Operating budgets can be further divided into program and responsibility budgets. A program budget shows the major "programs" an organization plans to undertake. This type of budget is valuable to the top management executive in examining the overall balance among programs. The

responsibility budget sets forth plans in terms of management responsible for their accomplishment. It provides a primary control device in that it is a statement of expected or standard performance against which actual performance can later be compared. An important aspect of the responsibility budget is that it forces managers to state as specifically as possible the goals and objectives they plan to accomplish during the budget period. If at all possible, specific objectives should be quantified to enhance performance comparison. Objectives are output measures and therefore should be stated in terms of standards or other performance indicators previously discussed.

Budgetary control requires that actual level of costs incurred during a period be compared with a desired level of costs for the same period. A desired level of costs may be related to a specific level of capacity. A "fixed" budget is one which is prepared for an assumed set of operating conditions and for a specified but estimated level of activity. Similarly, desired cost levels may vary with the level of activity or capacity utilization. A "flexible" budget is a set of alternative budget plans which pertain to different expected levels of activity. Performance appraisal is effected by comparing actual results achieved during the period with a similar level of activity budgeted for the same period.

The most effective way to budget maintenance costs is to determine maintenance requirements and then develop the costs of the maintenance service centers which when grouped together provide the related repair and technical functions. Use of historical costs in budget preparation is not good planning. The budget should provide for future occurences as opposed to "last year's figure plus 10%."

Maintenance budget preparation requires coordination with other departments which will be served by the maintenance activity. Organizations with comprehensive budget programs justify maintenance with detailed costs of component operations. Those organizations with less well developed budget programs tend to budget maintenance costs in a lump sum manner utilizing historical data.

The concept of responsibility costing was introduced earlier. Responsibility for maintenance costs is applicable to the budget process as well as to cost control. Maintenance costs are influenced by both maintenance personnel, who do the work and operating personnel who benefit from the maintenance services. Therefore, it is necessary to determine which manager is responsible for the maintenance costs incurred. Responsibility for maintenance costs can be broken down into three classifications as follows:

1. The nature and level of maintenance provided was fixed by executive management. The responsibility of maintenance costs lies with the individuals with decision-making authority. However, costs of work are distributed to user departments.

2. Maintenance services were continuously available to consuming departments. Costs of such work were charged to the consuming department at a standard rate.

3. Maintenance services were rendered on demand. Such costs are charged at a predetermined unit rate. The manager in charge of the user department was responsible for the number of service calls and the time required to effect repairs while the maintenance manager was responsible for unit costs of maintenance services.[25]

The fixed budget method is a popular technique employed by many organizations to budget maintenance costs. This is to be expected for an annual budget. However, at the maintenance department level it would be thought that various types of budgets would be employed depending upon which provided the greatest degree of control for the element of cost considered. This is not the case. Similarly, few organizations distinguish between repetitive, project and unscheduled work when budgeting maintenance costs.

Preparation of a fixed maintenance budget is accomplished considering each element of expense. Thus, maintenance man hours are estimated and totals are extended at applicable wage rates. Likewise, the costs of maintenance materials, supplies and contracted services must also be estimated. The addition of overhead essentially

completes the budget. An alternative approach to budget preparation involves focusing on the equipment to be maintained. Under this method, costs are budgeted for each major item of equipment or system to be maintained. It is necessary to scrutinize inspection reports and unit machine maintenance records to guide the estimates of future maintenance costs.

Fixed budgets rely heavily upon past maintenance records. The planned level of operations may motivate the attitudes of management to increase or reduce maintenance expenditures. However, experience indicates that past practices tend to persist. Fixed budgets aid in keeping expenditures within budgeted levels but they contribute very little toward improvement of maintenance service and its cost.[25]

Flexible budgets are widely used throughout industry for controlling manufacturing costs. Certain manufacturing costs are directly traceable to a product and vary in direct proportion to the volume of production. Essentially, a flexible budget is the presentation of estimated costs at various levels of volume. The behavior of maintenance costs are such that flexible budgeting cannot control the elements of cost.

The absence of substantive measures of maintenance output makes it necessary to correlate the costs of maintenance with an indirect index of maintenance activity

such as direct labor hours. While production volume or level of operations does influence maintenance cost the relationship is imperfect. Additionally, maintenance can be deferred to reduce short-run maintenance costs. Thus, any relationship existing between maintenance costs and volume are obscured by time. Flexible budgeting has proven effective as a means of developing rates for costing of maintenance work but remains largely ineffective for controlling maintenance costs.

Program or project budgets are rarely used when developing the maintenance budget. Organizations which employ such techniques usually use one of the following two methods:

1. Budget project maintenance in a lump sum and review expenditure proposals as they arise.
2. Develop an annual project maintenance budget by planning individual projects to be undertaken.[25]

The first method is characterized by a lack of economic evaluation. Normally, projects requiring small expenditures are approved and those requiring large amounts of funds are deferred. Thus, funds tend to be consumed by low-cost projects even though they may not be the most desirable.

The second method recognizes the fact that the maintenance projects may require capital investment. Maintenance expenditures which are currently made in

anticipation of future benefits fall into this category. Therefore, maintenance project proposals require the same scrutiny and economic evaluation as capital expenditure proposals.

It was previously stated that the budget is a management tool for planning and control. Control requires that cost information be reported in a form that will enable comparison. There is considerably more detail necessary in final reporting of cost information to be used for cost control than is necessary for accounting purposes. Therefore, methods of maintenance accounting will be subsequently treated.

F. MAINTENANCE ACCOUNTING

The concept of Terotechnology was introduced in the section dealing with maintenance objectives. Again, Terotechnology is "a combination of management, financial, engineering and other practices applied to physical assets in the pursuit of economic life cycle costs." From the accountant's point of view, Terotechnology is knowing in financial terms the effect of "what has happened, what is happening and what will happen" to any relative asset so as to optimize maintenance costs and organizational operations.[26]

The accountant is responsible for maintaining records which provide most of the basic data for controlling

maintenance costs. This data serves two purposes. First, it enhances the functions of planning and control for maintenance management. Second, it enables the accumulation of costs required for summary financial reports. Too often, accountants become engrossed with the production of numerical statements. This debilitates innovation which could lead to more efficient operations.

Maintenance accounting is not a substitute for management accounting. Rather, maintenance accounting should be designed as part of the overall control system which focuses on one area of the organization's activities. Therefore, maintenance accounting should be a subsidiary part of the management accounts and other control procedures.

The role of the accountant is one of an information supplier. In this instance, information is supplied to maintenance management to enhance decision making. The information provided for such purposes must be relevant or it will be useless. It follows, then, that both technical and financial information will enable maintenance management to know the history and forecast the future of systems/equipment which it has designated as significant. This requires that the accountant have an appreciation of the accounts from a different prespective; that of maintenance management. From this frame of reference,

current accounting practices have several weaknesses. Important for this purpose is the shortcoming in the area of cost collection. Normally, accountants collect costs by cost centers which are usually departments of the organization. However, maintenance management is concerned with the costs of maintaining systems or items of equipment. Thus, a paradox exists.

A recent report published by the General Accounting Office (GAO) recognized the need for improved cost accounting procedures for depot maintenance activities.[27] The report focuses on implementation problems of a system whose primary objective is the accumulation of the costs of a depot maintenance activity as they relate to the systems supported or items maintained. Thus, GAO realized the existence of the paradox and is pressuring the Department of Defense to conclude implementation of a uniform cost accounting system for depot maintenance.

Underlying any maintenance system is a paperwork system. The paperwork system is an information flow that coincides with the design of the organization. Briefly, the essential elements of such a system will be described. This is considered necessary because maintenance management needs a process for request of services, authorization and execution of operations. Additionally, it is necessary

to account for the costs of labor and materials, to establish a data base and to learn methods for minimizing the costs of maintenance and downtime in the future.

An important feature of any maintenance system is classification of work. The number of forms in the system can be minimized if work is coded and classified by type of activity (ie. preventive maintenance, emergency repair, routine repair, overhaul, etc.). Work classification aids in cost analysis by separating true maintenance costs from activities not related to keeping systems, equipment and facilities in an operable condition. It does not, however, enable the determination of individual equipment costs or those systems/equipment with exceptionally high maintenance costs.

All maintenance should be initiated in writing to prevent unnecessary and unauthorized work and to develop a history of work done segregated by system or equipment type. Maintenance request forms should be standardized and provide adequate detail to develop a history or routine repair data base for each system or item of equipment. Data processing cards may be employed for this purpose so that cost accumulation by system, equipment, department or other feature may be printed out. Additionally, this will allow for the automatic accumulation of maintenance history for each type of system or equipment and will eliminate manual posting to historical records.

Work order forms are appropriate for estimating the costs of maintenance or when the authorization to accomplish routine work such as preventive maintenance will remain open over a period of time. The work order should identify what is to be done, where, when and by whom and should provide for pertinent cost accumulation.

It is essential that work time be recorded accurately if meaningful cost reports are to be established. One such method is use of a time clock. This is especially suitable for fabrication work where time clocks are in close proximity to the work location. This method is less desirable for emergency work because of excessive travel to and from work locations. Time spent on a job should be noted on the work order and approved by a foreman. Daily time cards are a second method of recording work time. This requires that the card be maintained in the employee's possession so that annotations of account or job order numbers and times worked on each job may be made. Again, data processing cards may be used for this purpose to hasten cost collection and information processing.[17]

A cost accounting system that is to provide useful information for purposes of control must identify costs with responsibility centers. Two types of such systems are job order systems and process systems. Most maintenance work is accounted for by job order systems because such work

is a series of separate and distinct jobs. Job order systems employ the paperwork system previously described. Job order costing segregates and financially controls costs by individual job and also provides a source for billing customers. Cost segregation enables a comparison between actual and estimated costs for work performed.

It is necessary that maintenance management be provided with cost information in a number of different ways. A cost collection system based on codes will achieve this. Such a system requires that type of work be coded, type of system or equipment maintained be coded, cause of repair, customer department, etc. With a viable code system cost summaries by job, type of system, preventive maintenance programs, man-hour utilization and emergency repairs can be provided. Automatic data processing capabilities provide the flexibility necessary to track systems or equipment with high maintenance costs. Information of this nature would allow maintenance management to determine trends and areas requiring increased attention. Use of variance analysis, ratio analysis and graphical illustrations would enhance control.

It is important to realize that maintenance management requires an accounting system designed to meet its own internal needs and not those of the operational organization. The development of such a system does not involve major

changes in existing accounting systems. What is required are minor modifications to provide maintenance management with the information needed. A vital ingredient in the development of a maintenance accounting system is communication between the accountant and maintenance management. With improved communications the accountant will better understand the information needs of the maintenance departments.

A coded maintenance accounting system was developed for the depot-level maintenance program at PMTC. The system was designed by the Design and Engineering Department to meet management information needs. The system was considered necessary because information provided in periodic financial reports was considered inadequate. The information was considered inadequate in two respects. First, the information was not timely in nature. That is, the financial reports were prepared too late to be used for decision making. Second, the information was not relevant for decision making purposes. The information provided was historical in nature and represented record keeping as opposed to data for management decisions.

Interviews conducted with executives from both the Accounting Division and the Design and Engineering Department revealed that a communication gap exists. The

Accounting Division feels that the maintenance accounting system described complicates maintenance management. The Design and Engineering Department believes the maintenance accounting function should be accomplished by the Accounting Division. It is felt that the need for a maintenance accounting system that would provide management with timely and relevant information for decision making purposes is real. The Accounting Division possesses the local expertise in the areas of cost accounting, financial reporting and information systems development. Therefore, it is plausible that the Accounting Division provide assistance to the Design and Engineering Departments in their ongoing effort to further develop and improve its maintenance accounting system. Ideally, the Design and Engineering department hopes for an on line information system supported by a strong data base. Their ultimate goal is to be able to determine optimum maintenance cycles for each major system or item of equipment and an accurate projection of the costs involved with each scheduled maintenance action.

G. SUMMARY

A depot-level maintenance organization is a specialized repair facility which performs major repair and modifications, overhaul and calibration of major systems and equipment. At PMTC, the DLM program operates a facility to repair and modify radar, telemetry,

communication and other technically complex systems and equipment. Their objective is to provide maximum availability of range instrumentation without decreasing quality of system performance at minimum cost. The requirement to work within fixed budget constraints necessitates that their operation be as efficient as possible.

Attainment of this goal demands full utilization of available resources. A sound program of preventive maintenance enables scheduling of resources to optimize output. The direct results of such a program are reduced equipment downtime, preservation of assets and reduced labor overtime.

Management of such a maintenance organization, especially one constrained by funding limitations, calls for a strong system of controls. Management must plan for the maintenance to be accomplished, employ measuring techniques to determine the degree to which the plan is being achieved and realize why the plan was not attained. Similar requirements are true for the costs of maintenance. Management must understand the limit of available funds; what maintenance programs are drawing funds; the purpose of the program; and, the costs and benefits associated with those programs.

Employment of techniques such as variance and ratio analysis clue management as to potential problems. Similarly, trend analysis through graphic illustrations can provide insight into the operation of a maintenance department.

Budgetary control enables maintenance management to allocate funds and other resources to repair, refurbish or modernize systems and equipment. Accounting collects the costs of repair, refurbishment and modernization of those systems and equipment. Cost control provides maintenance management with tools necessary to keep costs at their planned level. Management must know if costs exceed their planned level and must also recognize the underlying factors which caused the difference.

Maintenance management must have knowledge of equipment with excessive maintenance costs. Equipment with excessive maintenance costs may be less costly to replace than to maintain. Customer departments with excessive maintenance costs may be abusing or improperly operating equipment. Thus, the maintenance organization must expend its resources unnecessarily to correct for the shortcomings of others. The need for maintenance accounting is real. Maintenance management must be provided with relevant and timely information for decision making purposes.

V. FINANCIAL MANAGEMENT AT PMTC

A. NAVY INDUSTRIAL FUND

The Navy Industrial Fund (NIF) is a revolving fund which is used to finance the operations of designated industrial and commercial type activities. A revolving fund commences operations with an initial funding by Congress which establishes the corpus. Having received initial funding, orders are taken to perform work. The work is paid for from the corpus and customers are billed for services provided. Customers reimburse the industrial activity and the corpus is replenished.

The primary purpose of NIF was to provide an environment similar to that of private industry which would encourage better management. Improved management would be accomplished through:

1. Creation of a contractual relationship between NIF and customer.
2. A cost accounting system which identified costs with specific jobs.
3. Flexibility, derived from the use of capital which is free of the Congressional appropriation cycle.

The concept of accrual accounting is important. Accrual accounting focuses on the uses of resources as opposed to outlays for resources. Thus, for example, labor costs represent labor performed as opposed to wages paid. In

contrast, Congressional appropriation accounting emphasizes the recording of expenditures (payments of funds) and obligations (legal reservation of funds).

Fiscal control is also provided by the NIF concept. The basic functions of control are:

1. Establishment of a plan.
2. Accumulation of performance data in the same terms as the plan.
3. Comparison of performance data with the plan.
4. Taking corrective action where there is a variance between performance and plans.

The above functions of control are listed in the Navcompt Manual and are very similar to the control process discussed in Chapter IV.[15] However, merely stating the ingredients of a control system does not effect control.

At PMTC, financial management is that control process which integrates technical strategic planning with the expenditure of resources. The Commander of PMTC is legally responsible for funds administration and is personally liable for over-obligation of the authorization. The Comptroller is the designated funds administrator for the Commander for all orders received.

PMTC is chartered as a modified Navy Industrial Fund activity. This is because some Departments operate under the Uniform Funding Policy instead of the NIF charter. As stated in Chapter III, the range and test cost centers

which comprise the Major Range and Test Facility Base charge customers direct costs only. Again, their overhead is funded institutionally by the Department of the Navy. The Comptroller at PMTC, in order to further financial management, established procedures to incorporate the range/test cost centers into the NIF environment. They are required to budget both direct and indirect costs. Direct costs are charged in the same manner as for NIF cost centers. The indirect costs are subjected to overhead review and approval as are NIF cost centers but are funded institutionally.

NIF and the Uniform Funding Policy are basically incompatible. This is because of the direct costing features of NIF. The introduction of the Uniform Funding Policy forced the industrial fund installation to behave as though it were two separate activities. However, the NIF organization structure effectively segregated those organizational components which operate under the Uniform Funding Policy.[28]

Another important feature of NIF is the performance budget which instills cost/price discipline. The industrial fund financial system reflects a limited market place environment. It requires a job order structure which clearly separates fixed overhead expense from direct costs. Through application of NIF costing principles to

institutionally funded overhead functions, PMTC found it could identify the traditional overhead functions in the MRTFB cost centers equally well as the NIF cost centers.

B. PMTC ACCOUNTING AND MANAGEMENT REPORTS

The NIF accounting system features double entry bookkeeping, accrual accounting, internal control over transactions and integration of cost accounting records with general ledger accounts. At PMTC, the details of the accounting system are delineated by NAVSO P-3045, Navy Industrial Fund Handbook for RDT&E Activities. Similarly, all NIF activities have certain traditional financial controls. They are:

1. Cost estimates and controls for monitoring costs-to preclude costs from exceeding the amounts authorized on customer orders.
2. Accounting controls-to prove the accuracy and proprietary nature of transactions and accounting records.
3. Budgetary controls-require that the financial plan and accumulation of actual data be on the same basis.[29]

NIF activities employ job order costing. When a customer order is received a job order is assigned to it. A job order is a cost accounting identification for collecting and accumulating costs which are related to the performance of the work requested in the customer order. Customers are then charged on the basis of the job order. Figure 7 provides a schematic of the collection of job order costs at a NIF activity.

JOB ORDER COSTS UNDER NAVY INDUSTRIAL FUND

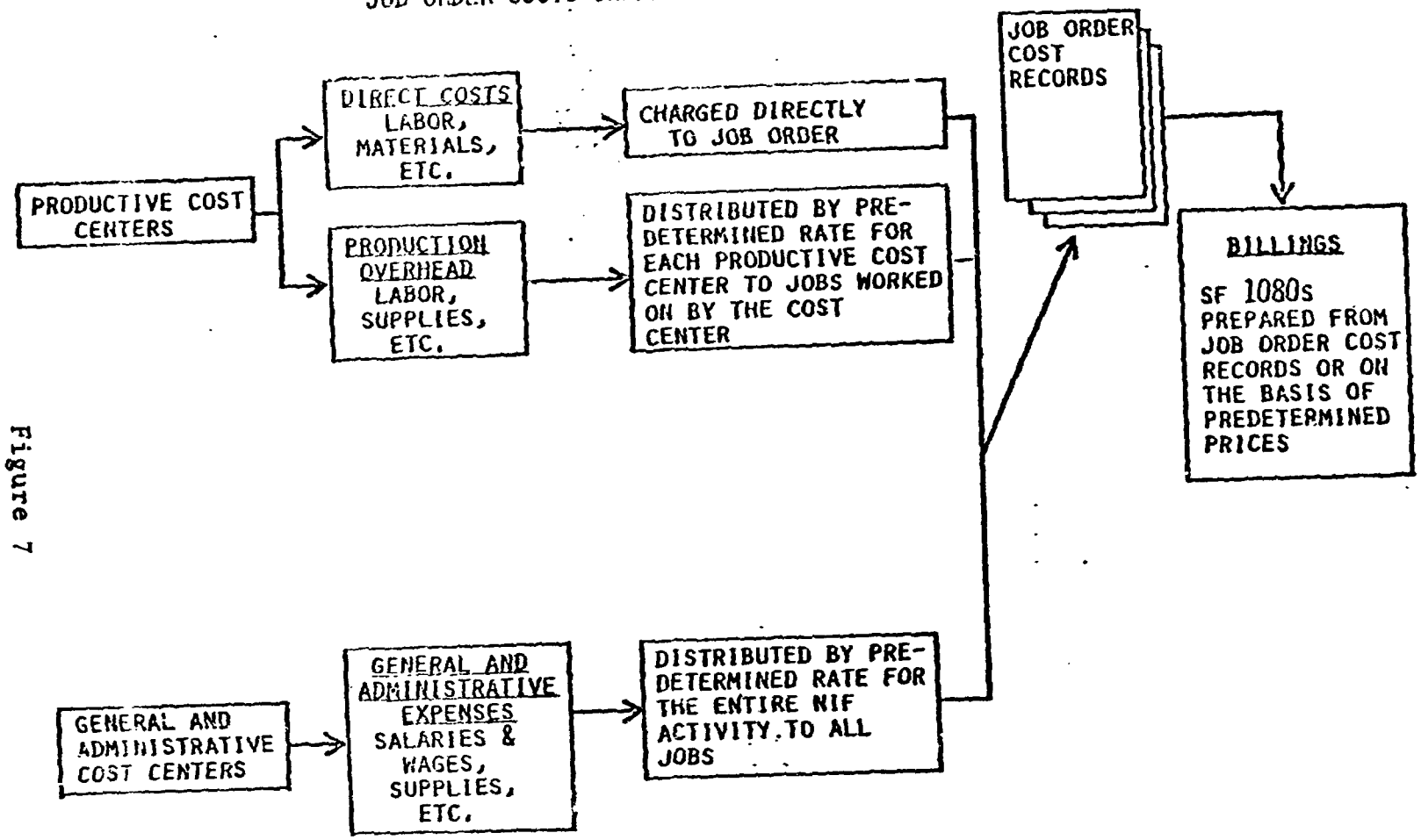


Figure 7

Job order costing is used extensively at PMTC. The documents and the flow of funds in this process will be described. The primary documents utilized in the direct funds administration are the Sponsor Order, Customer Order, Job Order and the Auxillary Job Order. The documents used in the funds administration process parallel the technical project management process from the task planning level to job management at the auxillary job order level.[14] Figure 8 illustrates the documents used in the funds administration process from planning through work accomplishment.

As a NIF activity, PMTC receives its revenues through sponsor's orders for work (including the institutional sponsor). This requires that project engineers negotiate for firm future orders to assure the availability of funds to support ongoing projects and in general, the entire work force. The project plan which is comprised of closely related task plans is the tool employed at PMTC for direct workload planning.

A direct workload planning system enables PMTC to organize its workload into packages which describe the work to be performed by specific organizational elements. From a financial management viewpoint direct workload plans:

1. Enhance sponsor funding prospects.
2. Provide workload projection data for budget and manpower decisions.

DIRECT FUNDS ADMINISTRATION

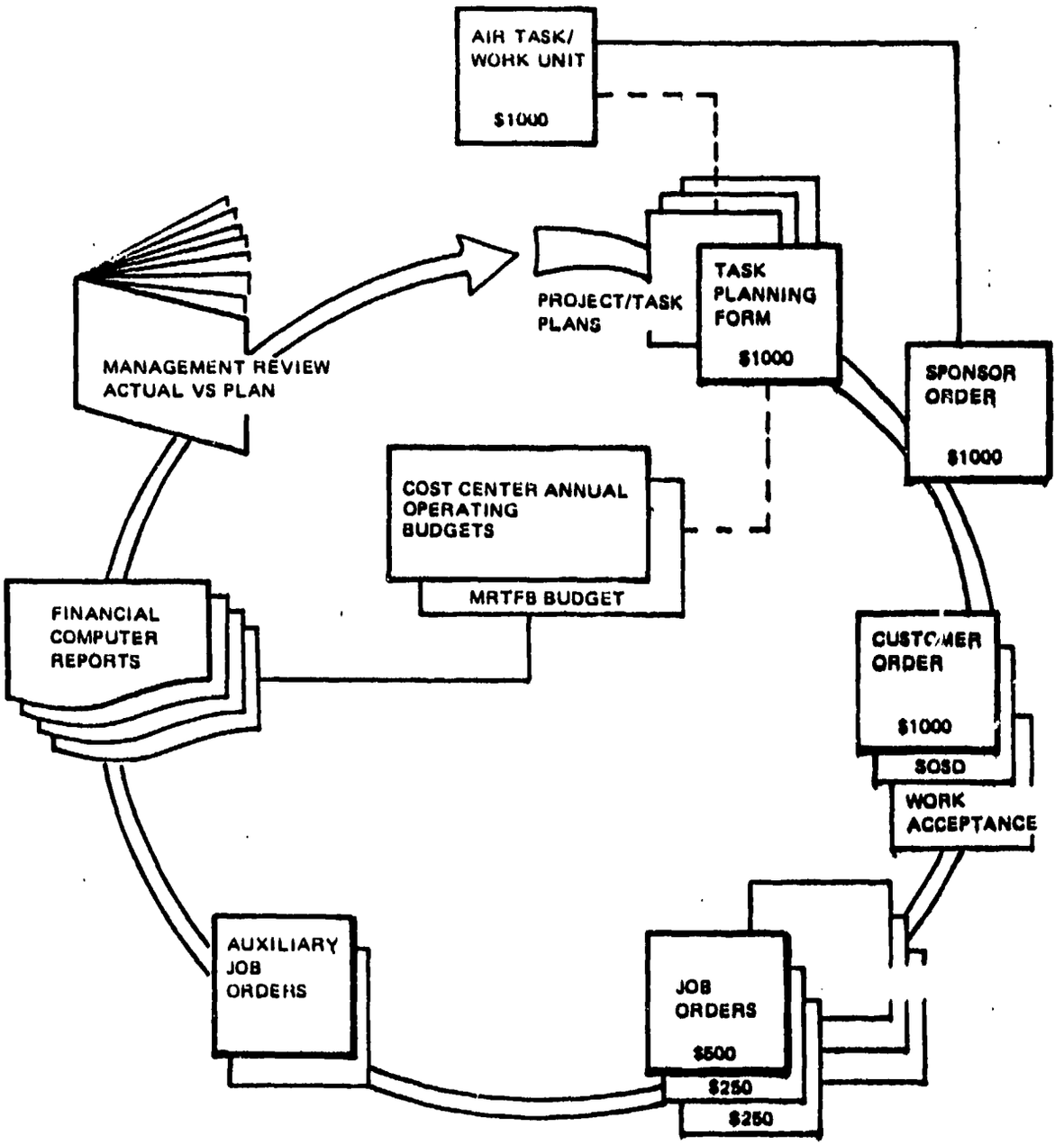


Figure 8

3. Improve funds administration.

4. Validate cost center operating budgets.[14]

Project plans and task plans are the building blocks of the workload planning system. These plans generally relate to funded Airtask's/Seatask's, work unit plans or other significant efforts.

The PMTC project/task planning system and the financial system are linked by the task planning form. This form is prepared by the task engineer or project engineering manager when the task plans are prepared. The Project Management Group (PMG) ensures that the task planning forms are prepared for each task under its cognizance and that data is compatible with the task plan.

A "sponsor order" is a local term used at PMTC to describe funding documents. Funding documents are received for performing various types of work and include work requests, project orders, military interdepartmental purchase requests (MIPERS) or deposits. Accepted sponsor orders are the source of authority to incur costs and perform work.

At PMTC, the Project Management Group is the single entry point for PMTC projects and tasks. All externally derived work is managed as projects by either the PMG or the Fleet Weapons Engineering Directorate. PMG only will be considered for this purpose. PMG manages

sponsor orders at PMTC to ensure:

1. Tasking documents contain sufficient information for workload acceptance.
2. Required material and facilities are available to provide the requested support.
3. Work can be accomplished within the time and funding limits provided.

Inherent in PMG's responsibilities is the financial management of assigned project funds in accordance with established project plans and sponsor funding.

The Budget and Finance Division review all funding documents and issue a unique sponsor order code to each document. They then prepare a work acceptance form and attach it to the funding document. These documents are then forwarded to PMG.

The Customer Order is a standard form for NIF activities used at PMTC which enables project engineering managers to authorize cost center managers to incur costs while accomplishing the work specified in the customer order. The customer order also specifies the allocation of sponsor funds and provides the basis for accumulating costs to be billed to the sponsor.

Customer orders for institutional funds are processed in a different manner. At PMTC, institutional funds are provided to support the four major range overhead functions: Range Operations; Improvement and Modernization; Station flying; and, Minor Construction and alterations.

Institutional funds are divided between range overhead (OR) which corresponds to NIF overhead and range technical functions (TF) which are those functions which directly support range operations. The Budget and Finance Division establishes a separate customer order for each range/test and range/test service cost center for that portion of the institutional budget that represents overhead. These customer orders equate to approved cost center overhead budgets. Similarly, customer orders are prepared for all technical functions which are institutionally funded including each procurement item of improvement and modernization (I&M) budget as well as local support for the I&M program. The customer orders for institutionally funded technical functions are based on cost center budgets and supporting cost data.[14]

The Comptroller also establishes a customer order to receive the distribution of general overhead from the range/test cost centers. This is accomplished monthly via a mechanized transfer process. Customer orders which were established to support institutional technical functions are not allocated overhead.

The Job Order (JO) is a cost accounting identification for collecting and accumulating costs. The JO is a subdivision of the customer order and is designed to collect costs relative to specified job objectives. Job orders can

only be opened after an authorized customer order has been issued. The task engineer in the job managing work center issues the JO to the job manager. The Job manager is located in the performing work center and commences work as specified upon receipt of the JO. If the job manager feels additional job level detail is required, he may issue an auxillary job order (AJO). Similar to a JO, an AJO is a cost accounting identification for collecting and accumulating costs, but can only be issued in support of an established JO. Common to both the JO and the AJO is the job order number. The job order number consists of a single alpha or numeric serialization which is added to the customer order number. Thus, the customer order, job order and auxillary job order are united via the customer order number/job order serialization. All labor and material charges associated with work performed are identified by job order, thereby emphasizing its importance. Therefore, it is necessary that all labor distribution cards, requisitions, vouchers and other related documents used for identifying charges have proper job order numbers.

Cost information is collected through the job orders and auxillary job orders and compiled into financial reports. The objective of the financial reporting system at PMTC is to assure management that operations are in accordance with regulations from higher authority and to aid management in

the decision-making process by identifying the financial status of the workload. The major factors which influenced the design of the PMTC financial reporting system were DOD and Navy regulations, funding policies, PMTC's mission and NIF accounting rules and regulations.[30]

Financial management reports at PMTC are categorized as project, functional, funding and miscellaneous. The reports are categorized in this manner because work is managed in a project and organizational/functional mode. Functional workload is subdivided into directorate, department, cost center, division and branch. Authorizations for these units of work are established by incoming funding documents and customer orders. These structured financial reports are produced biweekly.

The reports of primary importance to the depot-level maintenance program are those in the functional category. Functional reports identify cost and/or funding data within organizational units. The content and function of these reports is briefly outlined in Appendix D. These reports provide an abundance of information in great detail. However, the ability of management to review these reports and extract adequate information for decision making is questioned. It is not intended to disparage the structured financial reporting system. The need for these reports is well understood. Rather, the purpose is to

demonstrate the types of information provided and the methods of providing the information. In all cases, the primary means of collecting information is by cost center, division or branch.

It is suggested that there are improved methods of collecting and presenting information. The necessity to accumulate information by cost center is realized. However, different methods of arranging the information under the cost centers may provide management with more concise information for decision making. For example, the depot-level maintenance organization could have its "Cost Center Report" rearranged so that job orders are accumulated under the type of system or equipment maintained. Not only would the existing purpose of the "Cost Center Report" be met, it would also indicate to maintenance management where its labor, material and dollar resources are going.

Another factor that affects management decision-making ability is the volume of information provided for this purpose. It has been stated that the computer generated reports are too massive to be of benefit for decision-making purposes. It appears that inclusion of summaries prior to the detailed body of these reports may assist management decision-making efforts.

The timeliness of the information provided in these reports must be examined. Reports that are produced and

distributed biweekly are providing management with historical data. The need for more up-to-date information is real. The management of a large organization with a large budget and a large volume of daily transactions requires an almost instantaneous reporting system.

The future is bright for automated financial systems at PMTC. Over the past two decades the Department of the Navy has developed and maintained standard financial management systems for implementation at multiple activities. An exception to this practice has been NIF RDT&E activities. Therefore, the Navy Industrial Fund RDT&E Standard Automated Financial System (STAFS) is being developed. STAFS is being developed because of the recognized need for a single design, uniform ADP financial management system. It is anticipated that STAFS will be prototyped on 1 October 1980 and will begin implementation at NIF RDT&E activities commencing 1 October 1981.[31]

Advantages of STAFS include: elimination of manual intervention in the accounting process; automation of source data input; and, an on line interactive query up-date capability that will allow management to structure and format reports to meet their special requirements. Figure 9 provides an overview of STAFS.

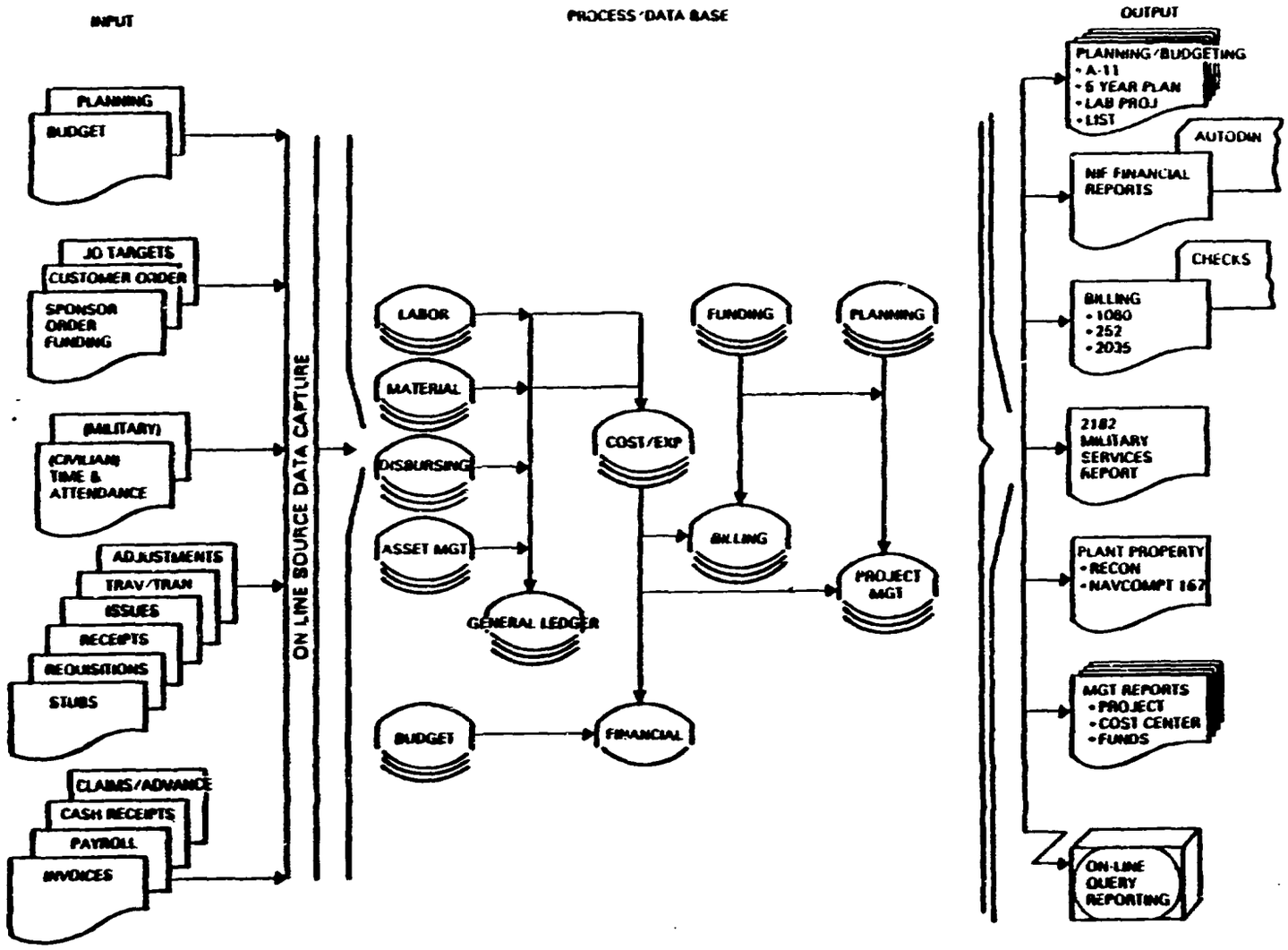


Figure 9

Overview of NIF RDT&E Standard Automated Financial System

VI. CONCLUSIONS

The concept of Terotechnology is appropriate for concluding this thesis. Again, "Terotechnology is a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economical life-cycle costs . . ." Control of maintenance costs over the life of range test equipment or instrumentation requires that maintenance costs be managed from the equipment design phase to equipment abandonment.

The theories of life-cycle costing and integrated logistic support were considered in detail. Application of these theories during the design and development of range systems and equipment at PMTC was reviewed. Interviews revealed that maintainability was low in priority during the range system/equipment development process.

The need for LCC and ILS analysis in the range system acquisition process is evidenced by the numerous, one-of-a-kind type equipment at PMTC. Lack of equipment standardization is a nemesis to DLM. The numerous, one-of-a-kind type equipment preclude utilization of standardized parts, test equipment and assembly-line techniques which would realize significant maintenance cost savings.

Employment of LCC and ILS would enable DLM management to anticipate future costs through determination of support requirements for the entire life of the system/equipment during its inception. Funding requirements will be known and can be allowed for in annual maintenance budgets.

The importance of establishing a maintenance plan for each system or item of equipment cannot be overemphasized. Failure to establish a maintenance plan during the system design phase motivates a system of emergency maintenance. The maintenance plan is the foundation for establishment of supportability requirements in system/equipment design.

DLM management does not influence range system/equipment design. However, it is responsible for controlling the level of maintenance costs incurred while supporting those systems. Many maintenance costs presently incurred could be avoided if a standardized LCC and ILS analysis package were established.

The "excessively obsolete condition of PMTC technical equipment" reflects inadequate funding levels for equipment replacement, improvement and modernization, and maintenance of range systems and equipment. Innovation is required in funding Major Range and Test Facility Bases. The Uniform Funding Policy was established to provide equitable service to range users at the expense of range management.

A recent notice (NAVCOMPTNOTE 7600 Subj.: Fixed asset accounting at industrial fund activities), which was promulgated too late for inclusion in the body of this thesis, provides policies and procedures for the procurement, budgeting, accounting and reporting of fixed assets by industrial fund activities.[32] The new policy of capitalizing real and personal property items having a unit acquisition cost of $1000 or more, regardless of the financing appropriation, providing the useful life expectancy is two years or more, is extremely important. Contributed fixed assets will be capitalized and transferred from memorandum accounts into "Assets Capitalized-Contributed Fixed Assets of the industrial fund." Similarly, purchased fixed assets, those financed by the industrial fund resources beginning FY-81 will be recorded in appropriate industrial fund general ledger accounts. Those assets, as delineated in the notice, will be depreciated on a straight line basis. A general ledger account, Reserve for Asset Acquisition, will be established. Annually, a portion of the Accumulated Operating Results gain equal to the amount for tools and equipment authorized to be financed by the industrial fund less estimated funded depreciation will be held in reserve in this account.

This new policy reflects the innovative attitude necessary to solve the funding problems associated with financing range equipment. It is considered a significant breakthrough for Navy industrial funded RDT&E activities.

The range system/equipment acquisition process was emphasized at PMTC. However, there was no reference to the process of abandoning obsolete, underutilized or duplicated range equipment. Costs associated with maintaining infrequently used equipment are excessive. Therefore, it is necessary to establish a formal decision-making process for equipment abandonment. This will prevent unnecessary duplication and elimination of resource expenditures to bring seldom-used equipment into an operational status.

The need to establish a relationship between inputs of the maintenance function and outputs from the maintenance function is realized. The ability to quantify the output of the maintenance organization is extremely difficult. Yet, a relationship between the value of resources employed during maintenance and the value of the benefits derived from maintenance must be established.

Indices can be employed for this purpose. Careful selection of a few indicators which relate a form of input to a measurable output can be invaluable. Not only can the indicators be used to control costs, they can also indicate trends and establish a form of budgetary control.

Maintenance indicators must relate resource inputs to a form of measurable activity of the organization to be useful for budgetary control. For example, a relationship between direct maintenance manhours and range operation hours can be established. During planning, this gross relationship can be employed to determine a "ball park" figure for labor costs for an estimated level of planned range activity. Perhaps an improved method is establishment of a relationship between maintenance costs and range operating costs. More specifically, the relationship of the costs of maintaining a specific range system with the costs of operating that same system for a similar period of time. A method of linking resource inputs into the maintenance organization with organizational outputs must be established.

The job order costing system at PMTC effectively collects the necessary cost information required by DLM management. However, the financial reporting system does not provide the data necessary for effective maintenance decisions, nor is the data provided in a timely fashion. It must be realized that the information needs of maintenance management are unique and differ significantly from the needs of general management.

It is felt that the true costs of maintaining range systems are not known. This is because maintenance costs

at the organizational level are not identified. Organizational level costs must be identified to realize the full cost associated with maintaining range systems and equipment.

DLM management exerts influence on a small portion of the life-cycle maintenance cost of range systems or equipment. This influence is normally restricted to daily activities which actually involve overhaul, calibration, maintenance and repair of range instrumentation. Maintenance cost control over the life of range systems can be effected to a far greater extent during the design of range systems. The ingredient necessary to ensure control is maintenance accounting information and reporting that provides feedback indicating the necessity for corrective action.

VII. RECOMMENDATIONS

The goal of reducing obsolete equipment is expedient. This goal can be accomplished by: replacing existing obsolete equipment; upgrading obsolete equipment to an acceptable condition; or, providing a sound program of scheduled maintenance that will prevent range instrumentation from deteriorating to an obsolete condition. The objectives of the DLM program include the latter. However, the requirement to operate within funding and labor constraints precludes the accomplishment of all maintenance effort necessary to achieve this goal. Some maintenance tasks will be partially completed, others will be deferred until accomplishment is feasible.

These constraints require that DLM management employ its resources as effectively as possible and optimize work accomplishment with the limited funds and resources available. Expenditures and maintenance costs must be maintained within planned levels.

The following are recommended as directions to pursue in the attainment of cost control:

1. Implement a program for LCC/ILS analysis early in range system or equipment design stages. This will identify support requirements and facilitate planning for support in future years.

2. Establish an interface between the range system design and development organization and DLM management. Communication between these organizations may enhance future support and may result in a more standardized, integrated range system.

3. Study the factors which indicate the need to abandon items of range equipment. A formal decision-making process for equipment replacement is necessary.

4. DLM management should begin transitioning their maintenance accounting system to ensure compatibility with STAFS. Involvement with STAFS during its infancy at PMTC could yield great dividends. Studies should be completed to investigate improved report formats. Utilization of computer scientists or computer systems managers is recommended. Finally, lobbying should be commenced to ensure terminals are strategically located for use throughout the DLM organization.

5. Investigate methods of relating resource inputs into the maintenance function to organizational output. The gathering of historical data and utilization of correlation and regression techniques could establish solid bases on which to reference indicators of maintenance performance.

APPENDIX A

PROBLEMS AFFECTING MAJOR RANGE AND TEST FACILITY BASES

A. LABOR FORCE

A major problem facing PMTC which affects the size and ability of the workforce is increased salary and career opportunities which exist in the private sector. This matter continues to deplete the technical workforce and increase the difficulty in maintaining a viable technical community. The minimum civilian requirement to accomplish PMTC's mission has been assessed at 3700 full-time permanent employees. While both direct project workload and funding have increased at PMTC the manpower shortfall remains critical. Steps to alleviate this difficulty include intensified college recruiting and expansion of paid advertising campaigns for technical personnel.[33]

B. AGING EQUIPMENT

Another major problem area which impacts all Navy Major Range and Test Facility Bases (MRTFB) is the rapid advancement of technology and the age of existing equipment and facilities. As weapons and weapon systems undergoing development, test and evaluation increase in sophistication, so must the equipment and facilities which provide

development support increase in sophistication. This matter is exemplified by the AN/FPS-16 tracking radars at PMTC. These systems were provided in the late 1950's and are over twenty years old. Although radar has grown enormously in accuracy and capability during the past thirty years, these systems continue to provide the basis for major electronic metric measurements. It has been necessary to continually modernize and improve these systems in order to maintain their viability. Figure 10 illustrates the age of equipment located at PMTC.

This problem is not unique to PMTC. The Naval Air Test Center (NATC) located at Patuxent River, Maryland is comprised of test and evaluation facilities and equipment with a replacement value of $117.9 million. Approximately 62% of these facilities and equipment are beyond their useful economic life. This situation is evident in areas of airborne computers, mission systems software and other technical areas where NATC does not have the equipment and facilities to conduct the most cost/effective T&E. Similar to PMTC, NATC range instrumentation and computer systems do not have sufficient size and speed capability to handle the existing and increased workload that will occur in the future.[34]

The Naval Weapons Center (NWC) at China Lake, California is also adversely affected by aging equipment.

Age of Equipment at Pacific Missile Test Center

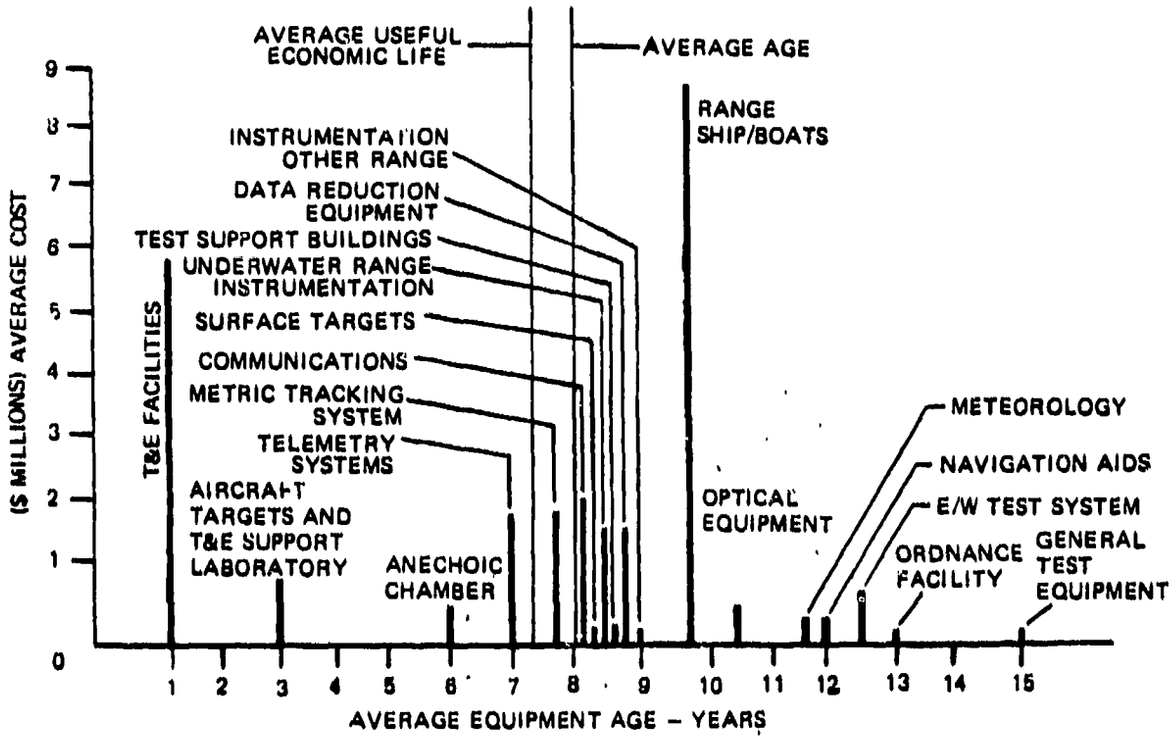


Figure 10

Seventy-six percent of the instrumentation supporting the air and ground ranges and the environmental, propulsion and warhead facilities have exceeded their useful operating lives of 8 years. The average age of NWC's T&E instrumentation is 14 years old. Maintenance costs for this equipment will soon begin to spiral.

In 1977, NWC had a 3 year deficit of over $9 million in maintenance costs. The result of this was that many major electronic and mechanical systems were provided with only "breakdown maintenance." This resulted in a gradual reduction in operational reliability.

NWC's difficulties are exacerbated by the fact that many manufacturers of the radar, optical, computer and data-gathering instruments no longer stock or manufacture parts. Additionally, some vendors are no longer in business.

A life-cycle cost analysis was conducted at NWC to scrutinize the problems associated with maintaining range instrumentation that has exceeded its life expectancy. The analysis determined that the cost of maintaining communications equipment and radars averaging 12 years old has increased about 30% to 38% each year and this effect is financially compounded. Again, this problem is aggravated by the fact that many instrument lines have been discontinued and this makes spare parts harder and more expensive to obtain. When parts are no longer

available commercially they must be specially manufactured or cannibalized from surplus equipment. As instrumentation passes its normal life expectancy of 7 to 10 years breakdowns become more frequent, reliability decreases, accurate calibration becomes impossible and maintenance costs begin to spiral.[35]

C. SUMMARY

The age of equipment and facilities at MRTFB's was elaborated upon to emphasize the problems facing the depot-level maintenance organization. The maintenance organization must work within the constraints of fixed budgets and manpower ceilings while the costs of maintaining aging equipment spiral and the procurement of additional equipment requiring maintenance continues. Adding to this problem is the fact that the technical workforce is being depleted by more lucrative opportunities in the private sector.

APPENDIX B

MAJOR SYSTEM ACQUISITION

The Office of Management and Budget established its policies regarding major system acquisition in OMB Circular number A-109 on April 5, 1976. The circular was generated from growing concern over the effectiveness of management of major system acquisitions. Its intent was to reduce cost overruns and diminish the controversy of the past 20 years on whether new systems were needed.

OMB circular number A-109 specifies key decisions and outlines a logical sequence of activities in the major system acquisition process. Figure 11 illustrates the major system acquisition cycle. Briefly, important items in the cycle will be discussed.

Each system acquisition program has unique features. No two systems are alike and differences in time, cost, technology and management must be recognized. Despite these many differences, the basic acquisition process is common to all programs.

The first step in the acquisition cycle is the statement of need. The mission need statement must include the purpose of the system, capability the system will provide, time constraints, value of meeting the need,

MAJOR SYSTEM ACQUISITION CYCLE

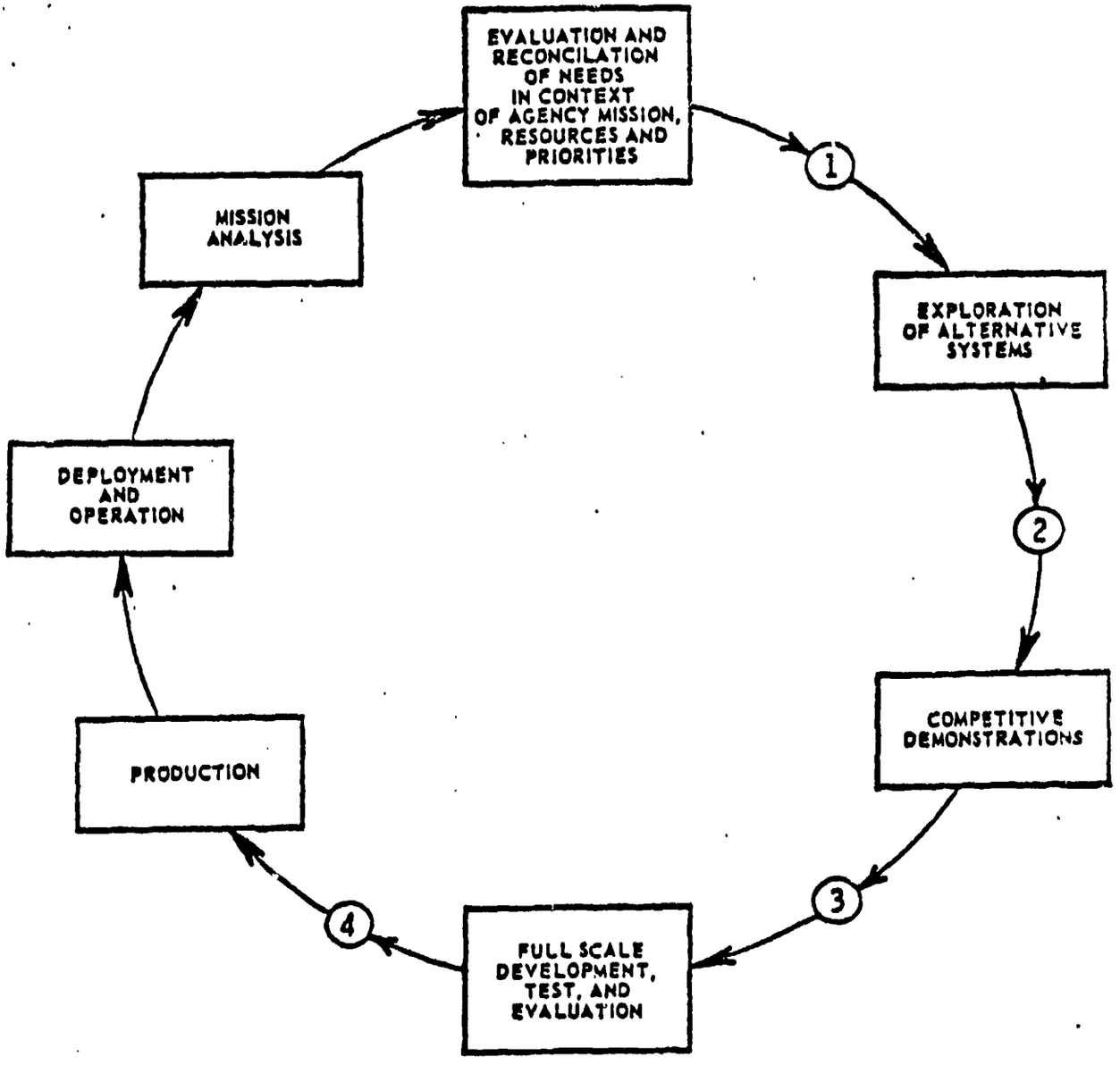


Figure 11

priority and operational constraints. The need statement is not to be stated in terms of specific equipment which may satisfy the need. Additionally, mission need entails a required capability which includes cost and schedule considerations.

Approval of mission need starts the acquisition process by granting authority to explore alternative system design concepts. A system design concept means an idea expressed in terms of performance, capabilities and hardware/software characteristics which will operate to satisfy the mission need.[36]

The next step in the cycle is that of competitive demonstrations. Competitive demonstrations are intended to verify that the system design concepts are sound and are capable of performing in an operational environment. Additionally, competitive demonstrations provide a basis for selection of the system design concept(s) which will be continued into full-scale development.[37]

The final step of the major system acquisition cycle to be discussed for this purpose is full-scale development/initial production. Full-scale development, including limited production may be approved when the mission need and program objectives are reaffirmed and competitive demonstration results verify that the system design concept is sound. Full production may be approved

when system performance has been satisfactorily tested, independent of the agency development and user organizations and evaluated in an environment that is expected under operational conditions. The final selection of a system and a contractor for full-scale development and production is to be made based upon system performance, costs of acquisition and ownership and demonstrated reliability and capability of the contractor to meet program objectives.

The Secretary of Defense issued Department of Defense Directive 5000.1 which implemented OMB circular A-109. The directive applies to those programs which are designated as "major" system acquisition programs. System programs involving an anticipated cost of $75 million in research, development, test and evaluation (RDT&E) or $300 million in production shall be considered for designation as major system acquisitions. Additionally, system programs not designated as major will be governed by the DOD directive.[38]

Similar to the OMB circular A-109, the system acquisition process established in the DOD directive is a sequence of decision events designed to achieve the established program objectives. As shown in figure 12, the process is very similar to that discussed previously.

Briefly, the documentation for each milestone decision point will be considered. Milestone 0 corresponds to the

LIFE CYCLE OF MAJOR SYSTEMS ACQUISITION

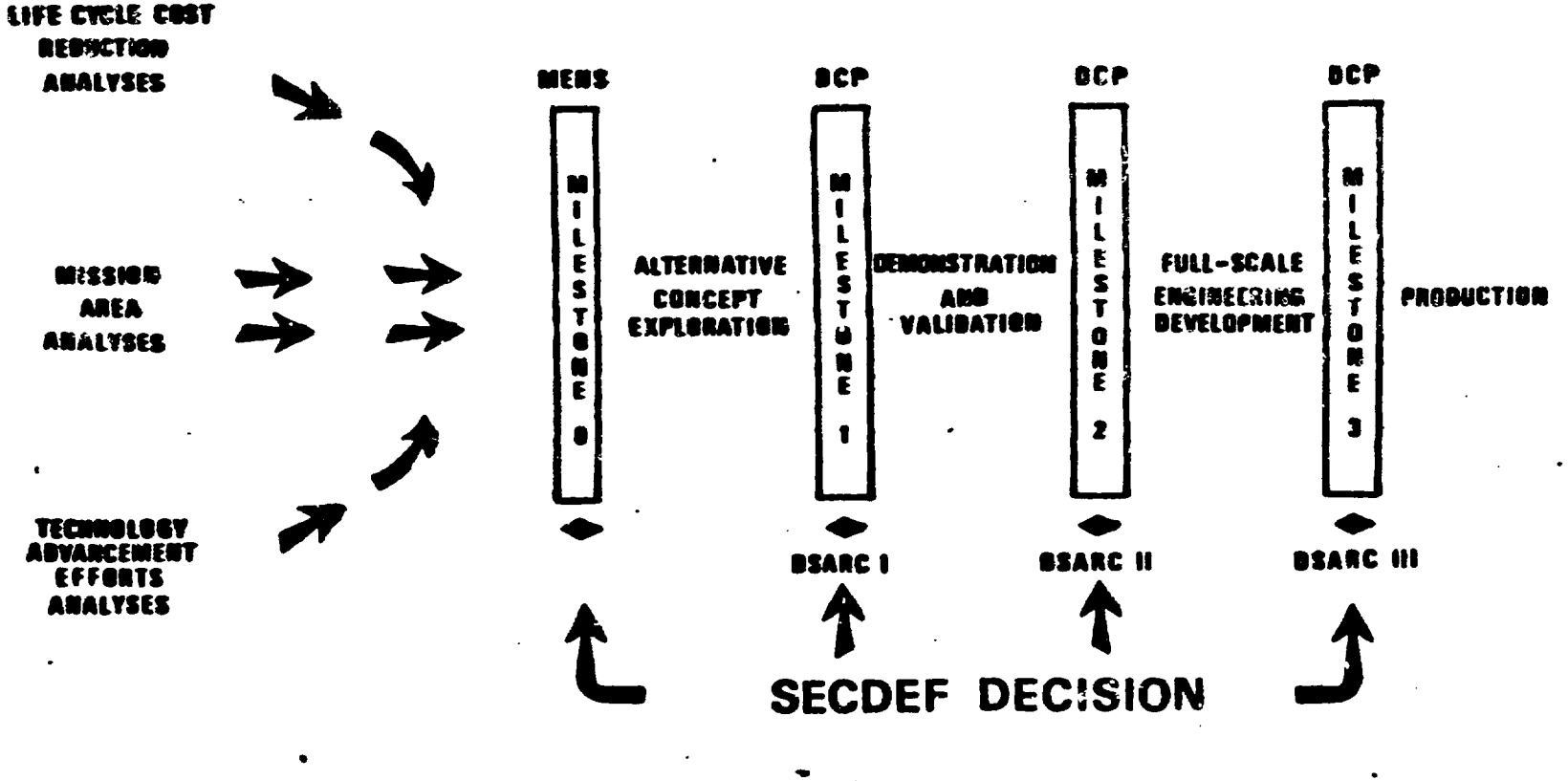


Figure 12

122

SOURCE: Researcher Originated

Mission Element Need Statement (MENS). Subsequent milestones I, II and III are documented by Decision Coordinating Papers (DCP). The DCP's are employed by the Defense System Acquisition Review Council (DSARC) for the purpose of making recommendations to the Secretary of Defense regarding each milestone decision. Each milestone is synonomous to a step in the major system acquisition cycle previously considered.

A policy stated in the DOD directive is important for this purpose. The statement deals with "Logistic Supportability" of the system being acquired. It states:

> "Logistic supportability shall be a design requirement as important as cost, schedule and performance. A continuous interface between the program management office and the manpower and logistics communities shall be maintained throughout the acquisition process."

The policy statement reflects the attitude that acquisition cost is no longer of utmost importance. The importance and value of providing for system support in the design stages of system development has been realized. The methodologies for assuring system support throughout its life cycle are important for this purpose. These techniques are Integrated Logistic Support and Life Cycle Costing.

APPENDIX C

IMPORTANT CONSIDERATIONS IN PLANNING ILS TASKS FOR LESS THAN MAJOR ACQUISITIONS

1. a. Definition of requirements for Built-in Test/ Built-in Test Equipment and Automatic Test Equipment

   b. Important Considerations-
   Support planning is heavily influenced by both the test thoroughness and fault isolation capability of BIT/BITE. When the task for determining BIT/ BITE requirements is included as a development phase contract task, the milestone for making the determination must occur as early as possible and the BIT capability must be clearly defined before definitive support planning can begin. Major impact is at the user level. Similarly, early consideration must be given to the use of automatic test equipment.

2. a. Definition of required system maintenance characteristics

   b. Important Considerations-
   This prerequisite applies particularly to maintenance characterictics which are not subject to the trade-off process during development. Careful attention must be given to maintenance characteristics which are to be imposed as a result of austere operational environments where support capability is limited; those resulting from mobility and safety considerations; and those necessary for compatibility with existing support systems and concepts.

3. a. Definition of required system reliability

   b. Important Considerations-
   Consideration must be given to factors affecting maintenance frequency (e.g., storage life, handling damage, test ambiguity, scheduled maintenance requirements) as well as the inherent reliability of the equipment.

4. a. Definition of quantitative contract support system requirements

   b. Important Considerations-
   Where contractual demonstration is required, quantitative requirements must be included in the development contract specifications. Appendix A provides guidance for meeting this requirement. Where demonstration is not justified, then quantitative goals should be established and trade-off criteria should be defined for inclusion in contract specifications.

5. a. Definition of qualitative support system requirements

   b. Important Considerations-
   Preliminary tasks may be necessary to determine the applicability of existing resources such as GFE, personnel classifications, facilities and transportation, handling, and storage concepts. These determinations should allow full consideration of alternatives which may offer economic or operational advantages as the development evolves.

6. a. Definition of Baseline Maintenance Concept

   b. Important Considerations-
   For limited development, this prerequisite applies only to the extent that the maintenance concept affects the specification of system maintenance characteristics (see 2.a. above). When the task for determining the baseline maintenance concept is deferred as a prerequisite and included as a contract task, then all tasks relative to support planning and logistic support system engineering must be deferred until the baseline concept is established.

7. a. Definition of support element baselines

   b. Important Considerations-
   Contractual commitments on the acquisition of support elements should be deferred until this prerequisite is satisfied. Whether accomplished in-house or as a contracted task, the support system baseline should be defined to the depth indicated by the examples of Appendix A, prior to acquisition of support elements.

8. a. Definition of task-oriented plan for production and evaluation of contractor support elements

   b. Important Considerations-
   Whether accomplished in-house or as a contracted task, 4.b. through 7.a. are also prerequisites for this task in a Development program. As in major acquisitions (see Chapter III), conceptual planning for ILS is accomplished initially by the government; however, in this case, it must be preceded by conceptual formulation of support system requirements.

9. a. Definition of baseline schedule for integration of contractor support elements with government support elements

   b. Important Considerations-
   Whether accomplished in-house or as a contracted task, 4.b. through 7.a. are also prerequisites for this task in a Development program. As in major acquisitions, conceptual planning for ILS is accomplished initially by the government; however, in this case, it must be preceded by conceptual formulation of support system requirements.

APPENDIX D

FUNCTIONAL FINANCIAL REPORTS IMPORTANT TO DLM

TITLE - MANAGEMENT COST CENTER ANALYSIS

CONTENT - Identifies by cost center, as appropriate, applied overhead, actual overhead, net rated costs, and direct labor hours; and analyzes, as appropriate, cost center profit/loss, over/under applied overhead, and general expense.

FUNCTION - To provide an analytical statement of cost center performance to budget.

TITLE - MANAGEMENT COST CENTER STATEMENT SUMMARY

CONTENT - Year-to-date cost by cost center

FUNCTION - To provide a summary listing of year-to-date labor hours consumed within each cost center; and to identify by cost category the status of unfilled orders.

TITLE - MANAGEMENT COST CENTER STATEMENT

CONTENT - Time and Cost data presented at the expense element level and totaled to the following categories:

- Net overhead cost
- Service cost
- Net direct institutional overhead
- Direct cost institutional technical function
- Direct cost with applied overhead
- Direct RDT&E A/C program cost

FUNCTION - To compare by cost center actual to budget

TITLE - THE COST CENTER REPORT

CONTENT - Year-to-date costs by job order within division.

FUNCTION - To provide detail listing of cost centers activity according to categories of work.

TITLE - THE DIVISION COST REPORT

CONTENT - Structural data includes:
Work center
Job order

FUNCTION - To provide detail year-to-date cost by division identifying specific liability account transactions, indirect and direct effort.

TITLE - THE BRANCH COST REPORT

CONTENT - Structural data includes:
Civilian/Military hours
Work center
Job order

FUNCTION - To provide detail year-to-date cost by branch identifying specific liability account transactions, indirect and direct effort.

TITLE - THE PMTC WEEKLY TRANSACTION REPORT

CONTENT - Detail week-to-date cost transactions.

FUNCTION - To provide sufficient detail as to satisfactorily respond to audit, correction, or analysis requirements imposed upon organization units.

TITLE - COMMITMENT AND OBLIGATION LISTING

CONTENT - Listing by work center of all NIF contingent liabilities.

FUNCTION - Identifies the status of unfilled orders by document number.

TITLE - SUMMARY STATUS OF JOB ORDER TARGET AMOUNTS

CONTENT - Job order authorizations, week-to-date and year-to-date cost by job managing work center. Totals provided by branch, division, department, and directorate.

FUNCTION - To provide functional managers the status of each job order managed within their organizational unit.

TITLE - CUMULATIVE MATERIAL EXPENDITURES REPORT

CONTENT - A listing of quarterly expenditures by document number.

FUNCTION - To provide a worksheet to research the status of obligating documents.

TITLE - DAILY LABOR UNALLOCATED COST CHARGES

CONTENT - A listing of unallocated labor hours and cost by employee.

FUNCTION - A worksheet for correcting unallocated labor.

TITLE - PERFORMANCE OF WORK REPORT

CONTENT - Structural data includes:
Request number
Auxilliary job order
Work center
Hours

FUNCTION - To monitor the cost of each "Request for performance of work" forwarded to the Public Works Department and/or to the Design and Engineering Department.

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